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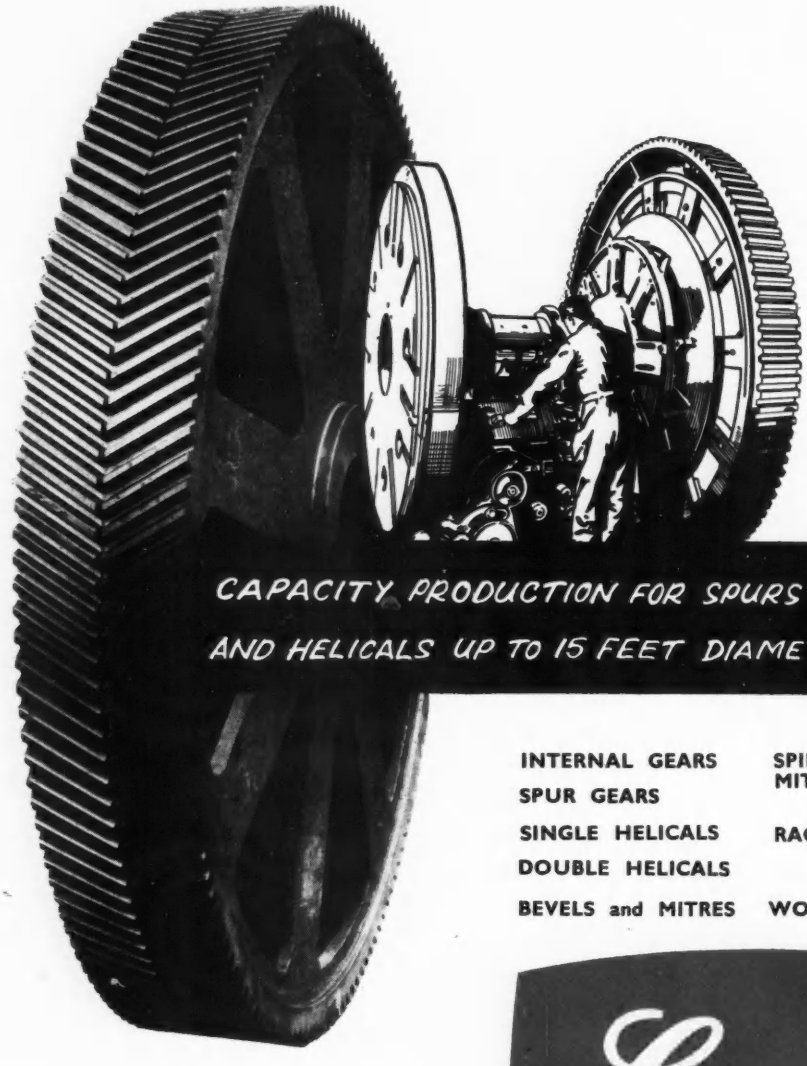

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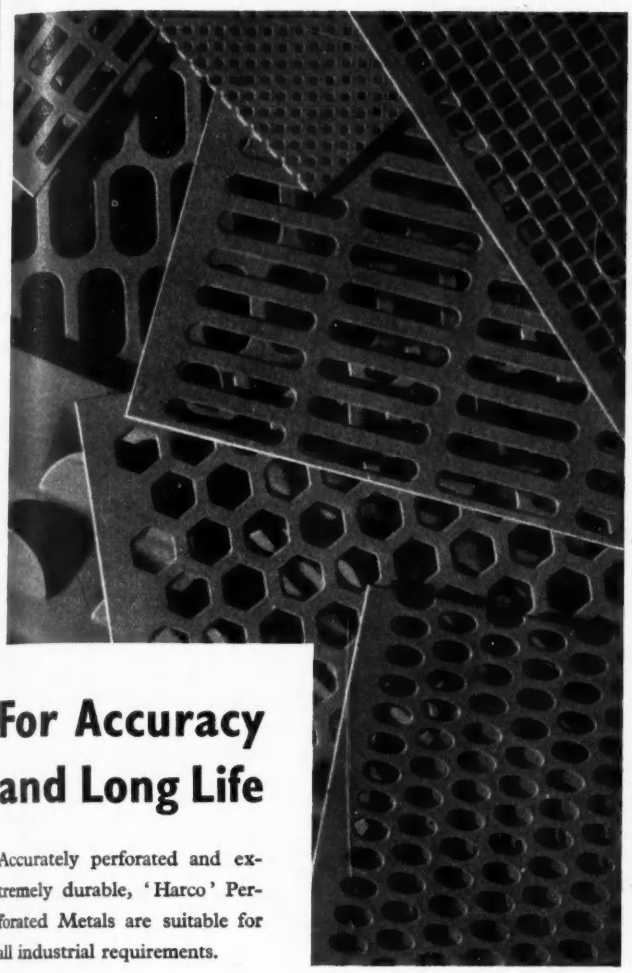

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THE ROYAL SHOW

Twice a year we take the opportunity to survey the activities of that large section of the engineering industry which is concerned with agriculture. The opportunity is presented by the comprehensive displays of farm machinery and implements which form the major part of the Royal Show, in July, and the Smithfield Show and Agricultural Machinery Exhibition, in December. The former takes place in a different part of the country every year ; the latter is always at Earls Court, in London. This year's Royal Show was held at Norwich last week, on a site at Costessey, which is well suited to the staging of such an event. For regular visitors, the show had all its familiar characteristics. So often it has been described as a large country fair, or as a pageant of British agriculture, or as a shop window for farm produce and agricultural machinery, all of which descriptions are partially correct. The attendance on the four days of the show totalled over 135,000, which can perhaps best be described as a good average. The expenditure incurred by the Royal Agricultural Society in erecting and dismantling the show runs into many thousands of pounds, and the costs which exhibitors must bear tend to increase every year. Despite the economic problems, however, the Royal Agricultural Society presses on vigorously with the work in which it has now been engaged for the last 118 years. As a learned society, it has contributed, and continues to contribute, much to the successful prosecution of British agriculture.

The work of the Royal Agricultural Society is known all over the world. But some of the important aspects of that work are perhaps apt to be overlooked in this day of highly mechanised agriculture. One of those aspects is the encouragement which the Society has given consistently for more than a century to the development of farm machinery of all kinds. That encouragement has been a powerful factor in bringing about the state of full mechanisation of work on the land which now prevails. We could not help reflecting upon it as we toured the extensive machinery section of this year's Royal Show. The last occasion on which the show was held at Norwich was forty-six years ago. Then, there were exhibited some of the machines which had taken part in competitive trials, organised by the Royal Agricultural Society, of " agricultural motors, driven by steam, oil, petrol or electricity, and capable of hauling direct in work a plough, cultivator, harvester or other agricultural implement." Steam power still predominated ; the internal combustion-engined tractor was then very much in its infancy. At the time, satisfaction was expressed that such tractors as were shown were " purely of British origin," though few people believed that the internal combustion engine would ultimately revolutionise the practice of agriculture. But that, in short, is exactly what has happened. Tractors of small, medium and large horsepowers, numerous examples of which were displayed at Norwich last week, now provide power for operating, as well as hauling, a remarkable array of field and farmyard machines and implements. The stage has been reached, in fact, at which the rate of agricultural machinery development is somewhat slower than it was. That is inevitable.

This year, therefore, was one of the occasions when it was difficult to find anything really new in the machinery section of the Royal Show. Moreover, we came away with the impression that there were not quite as many people, as in some years recently, who headed straight for the machinery stands as soon as they entered the showground. The reason for that, of course, may be a purely economic one associated with credit squeezes and the like. If the show is considered from the standpoint of a trade fair, we do not know if business for the manufacturers was good, bad or indifferent. On that count, therefore, it is heartening to learn from the Agricultural Engineers' Association that more than 60 per cent of the agricultural machinery's present output is being exported. Overseas sales are again on the increase. But the Royal Show is by no means wholly a trade fair. It continues to be, in so many respects, the summer meeting of a distinguished learned society, which has the traditional motto " Practice with Science." The show has a distinctly educational function, a function which, from an engineering point of view, we hope will not be overlooked. There are still paths of technical progress for agricultural engineers to pursue. The further development of grain drying, for example, is one of them and the more effective handling of materials in agriculture is another. In the rapid achievement of a highly mechanised agriculture, engineers have taken a major part. That is a fact which cannot be too often stressed ! We are confident that their efforts will not flag ; and we are equally confident that the Royal Agricultural Society will continue to encourage them in their endeavours.

DEMISE OR REBIRTH OF THE B.I.F. ?

A fortnight ago, as we reported in last week's issue, the President of the Board of Trade received a deputation from the Birmingham Chamber of Commerce to discuss the British Industries Fair at Castle Bromwich. Discussion is certainly needed ! It will be recalled that, some eighteen months ago, the Government decided no longer to hold that section of the fair which was formerly held in London, but the Birmingham Chamber of Commerce, which had always organised and financed the Birmingham section at Castle Bromwich, decided to assume complete control and to organise a fair this year. It was duly held. In the estimation of the Chamber of Commerce, though not, we think, of engineers, it was a success. But it is not to be held in 1958. The Chamber has recently had it in mind that the fair ought to be international, and it is upon the ground that it would be impracticable to organise an international fair for 1958 that the decision has been taken not to hold the fair at all. We applaud that decision. For though as a hardware fair the 1957 show may have been a success, it certainly was very far from being representative of British industry and it was notably unrepresentative of engineering. More damage than good to the industrial reputation of this country would have been done had it been held in the same form once more next year under the same title. Indeed, in the form which the B.I.F. has taken since the war it is probably already dead. There remains the possibility of reviving it as an international fair.

The Birmingham Chamber of Commerce is stressing that if Britain enters a European Free Trade Area it will be desirable to hold in this country general international fairs comparable with those held on the Continent. Yet even if that argument is regarded as uncontroversial, which it is not, the question must still be asked whether Castle Bromwich is the right place at which to hold an international trade fair. Can the existing buildings be regarded as satisfactory in comparison with those in which international fairs abroad are held ? Is there sufficient space available for expansion ? Can sufficiently big car parks be provided ? And is road and rail access really sufficient ? Furthermore, could the support of sufficient trade associations in this country be obtained to make the fair more truly representative of British industry ? As the whole trend in this country since the war has been towards the holding of specialised exhibitions we rather doubt it, even though the trend may possibly be rooted in the fact that no group of halls suitable for a great general fair exists. Our sympathies are, indeed, with the members of the Chamber. There are available at Castle Bromwich good, though far from excellent, exhibition buildings and grounds. But the British Industries Fair is no longer attractive to British industry. What then is to be done with Castle Bromwich ? Yet the head must rule the heart. We doubt whether British industry would support a general fair on the Continental model ; we doubt still more whether, supposing British industry was willing to support such a fair, Castle Bromwich is the right place to hold it. Perhaps the Chamber would do better to think along more parochial than more international lines. As a jibe in the past the letters B.I.F. were sometimes interpreted to mean Birmingham Industries Fair. Under that limiting title it might do better. Alternatively, the fair might be limited to hardware and ancillary trades. The question as to whether a great general international fair ought to be held in this country, we feel, is disconnected from the future of the B.I.F. For it to be a success new modern exhibition buildings comparable with those at Hanover would need to be erected and support by a substantial fraction of British trade associations would have to be assured. The Birmingham Chamber of Commerce has doubts whether it is the appropriate body to organise such a fair. We doubt it too.

The Engineer
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(JULY 10, 1857)

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FESTINIOG ENTHUSIASM

All small boys like playing at or with trains. Most of them grow out of it as they get older. A few by becoming railwaymen make the operation of a railway their life's task. Others, becoming engineers, learn how to lay out and build railways or to construct locomotives and rolling stock. But an even larger number, having no opportunity in later life to operate a railway or build rolling stock for it, still retain an enthusiasm for all things connected with railways. When they travel by train they always know what engine is at the front and what is the weight of the train. Stopwatch in hand they time it. Railway men as a class, from platelayers to managers, never lose interest even when they retire. Nor do men originally trained in railway workshops wherever else their lives may be spent. It was this widespread enthusiasm for railways which allowed the Festiniog Railway in North Wales to be rescued from decay in 1955. It is a 2ft gauge single line railway running from Portmadoc, on the coast, to Blaenau Festiniog 700ft up and 13¼ miles away. It was notable in the past as the first narrow gauge railway to apply steam traction successfully, as the first railway in Britain to introduce bogie coaches, and as the first narrow gauge railway to carry fare-paying passengers. It is now operated by the Festiniog Railway Society with the minimum of paid permanent staff and the maximum of volunteer effort by ex-railwaymen, present-day railwaymen and railway enthusiasts. When the Society assumed control in 1954 it acquired the wreck of a railway whose equipment had lain idle and untended for eight years. At the railway's works at Boston Lodge roofs leaked, floors were rotting and machine tools were rusting. In the yards grass, weeds and gorse bushes had grown so high as almost to conceal the trucks, coaches and locomotives that lay about just as they had been left in 1946 when the original company ceased to operate. The line itself was overgrown from end to end. Only enthusiasts—and somewhat mad enthusiasts at that—would ever have deemed it possible the railway could be got running again. But—thank Heaven ! —there are somewhat mad enthusiasts in this world. The railway is running again and as we note on another page we paid a visit to it last week. Chaos is being reduced to order, slowly maybe, but effectively. Enthusiasm has had its own reward. Firms, notably the Vulcan Foundry, Ltd., which has completely restored a Fairlie locomotive for the railway, are proving generous. Funds are slowly mounting both from the railway's earnings and from the subscriptions of new members of the Society. Everyone who has seen the work being done will wish the Society success in its efforts to open the railway from end to end.

A Seven Day Journal

Mists and Fogs from Industrial Processes

IN his annual report to the Minister of Housing and Local Government (H.M. Stationery Office, 2s. 6d.) the Chief Alkali Inspector for England and Wales states that fundamental research on the problem of mist formation is required. The question has been brought to the notice of the Department of Scientific and Industrial Research. The report indicates that this problem, which has existed in some degree for a long time, has become more pronounced since the last war. The actual masses emitted as a result of the various processes are said to be usually trivial, and in most cases the emissions are probably harmless. Nevertheless, complaint against the voluminous mists and fogs rolling from works is agreed to be justified. It is thought that such mists may be caused by moisture around hygroscopic nuclei, but effort toward solution in particular cases is not being relaxed while hypotheses of this kind are investigated.

By the end of last year 889 works had been registered under the Alkali, &c., Works Regulation Act, the operation of 1747 separate processes being involved. The number of works registered is smaller than before the last war, but production is much greater. The annual output of sulphuric acid has gone up from 800,000 to 2,000,000 tons, cement from 6,500,000 to 12,500,000 tons, and crude and process oils at petroleum refineries from 2,000,000 to 26,000,000 tons.

During last year 3896 visits of inspection were made, 397 to unregistered works and a further 63 in connection with colliery spoil banks. The total acidity of gases escaping into the air exceeded statutory limits on eight occasions, and there were fifteen failures to use "best practicable means" for preventing the escape of noxious and offensive gases. The marked improvement in maintenance and control is indicated by the reduction in the number of infractions—forty-eight were recorded in 1955. Eight spoil banks emitting an unhealthy amount of smoke or fume were visited at the request of the local authorities concerned, and five of these spoil banks responded sufficiently to treatment for the public hazard to disappear.

Road Research

THE annual report on road research for 1956 follows along very similar lines to its predecessors. Much valuable work is in progress in the Road Research Laboratory's "materials and methods of construction" division; for instance, advice on a drainage problem at Harlow saved £50,000 in a total cost of £300,000. But it is the remarks on road traffic and safety which command immediate attention as a problem of urgency on the national scale. The report states that if the present trend continues the disparity between the growth of traffic and the provision of adequate roads will widen. Road traffic has increased annually by 8 per cent since 1952, it is pointed out, and in spite of the increased number of road schemes congestion worsens.

Following recommendations from the Road Research Board about the need to consider the adequacy of present organisations, a special planning branch has now been set up by the Ministry of Transport and Civil Aviation to provide essential information for the future development of the national road programme. The Board has also formed a panel consisting of four county engineers and a city engineer assisted by representatives of the Ministry of Transport and Civil Aviation and of the Road Research Laboratory for assessing the economic benefits to be expected from proposed road improvements; the body meets regularly and each member is already applying a method put forward by the economics committee of the Board. In addition, with the co-operation of highway engineers and the police, "before-and-after" studies are being made of the economic benefits which result from some actual road improvements. Work is in hand on some fifteen schemes. The Board expresses the opinion that "economic returns to the country from the building of new roads have been grossly underestimated in the past," and these studies should provide a valuable check on this belief.

Road accident casualties continue to increase. The situation worsened slightly during the first ten months of 1956 (i.e. before Suez) as compared with the corresponding period for 1955. There was an increase of 3 per cent in accidents involving personal injuries. Deaths increased by 2 per cent during the period. The Board notes that the maximum speed of many present-day production cars approaches that of the racing cars of twenty years ago, and that the speed at which they are driven on the road is steadily rising. Some results of the special experiment in road safety being carried out in Slough are now available, although the detailed results will be published later.

Bond and Cracking in Reinforced Concrete

THE international organisation for collaboration between testing laboratories —R.I.L.E.M.—recently held a three-day symposium in Stockholm, when bond and cracking in reinforced concrete structures was discussed. Some 160 engineers from twenty-five countries took part with a representative group from Great Britain. Much of the discussion related to specialised investigations of the fundamental nature of bond and theoretical predictions of crack width and spacing. Comparisons between various reinforcing steels were made, and in the case of Continental and American contributions they related almost exclusively to deformed high-tensile steel. It was generally accepted that loading cracks rarely caused corrosion of reinforcement and widths of up to $^1/_{100}$in were considered acceptable. The greater sources of trouble were cracks caused by restraint upon shrinkage and temperature movement. Probably the most significant conclusion was that corrosion problems in reinforced concrete were almost exclusively due to poor quality concrete and not to loading cracks. A subject in which further knowledge was required was crack distribution and widths due to shear.

Natural Rubber Development in 1956

THE annual report of the Natural Rubber Development Board gives prominence to work on the increased use of rubber in road construction. Research was conducted not only in the Board's own laboratory in the U.S.A., but also in co-operation both with the Road Research Laboratory of the Department of Scientific and Industrial Research and with the British Rubber Producers' Research Association. Further effort was given, both at the Road Research Laboratory and by the British Rubber Producers' Research Association, to the production of stable mixtures of rubber and tar. Although the problem has proved difficult, success was achieved on a laboratory scale with certain kinds of tar, and road tests were envisaged. The report states that the incorporation of rubber in bituminous materials leads to a marked increase in resistance to deformation, as well as to reduced brittleness at low temperatures. Evidence from a trial on the Boston Manor road is reported to confirm this. A film entitled "Rubber in Roads" was completed in 1956 and given its first showing at the Public Works Exhibition. A one-day conference on rubber in engineering was held in London during the year. Over 400 members heard papers read on the use and properties of rubber.

Co-operation continued with the British Transport Commission and the British Rubber Producers' Research Association in connection with rubber components for railways. Rubber rail pads enjoyed particular attention. Trials were made in various Commonwealth countries also, and enthusiasm on the part of the railway authorities is reported.

Air Registration Board

THE Minister of Transport and Civil Aviation, Mr. Harold Watkinson, spoke at the annual luncheon of the Air Registration Board on Thursday last week. He expressed himself satisfied with the progress of the nationalised airways corporations over the last six years, and referred particularly to their equipment problem; he was dubious of the operational flexibility of the big jet liners, such as B.O.A.C. proposed to import. He believed that air transport operators must be given some protection and security of tenure, and said that the independent operators had done well in their peculiar circumstances.

The Chairman of the Board, Lord Brabazon of Tara, discussed the implications of the certification of aircraft under regulations foreign to those under which they were designed and built. He made the point that if he was asked to validate a foreign certificate, the aircraft must conform with British standards. Nevertheless, he respected the United States standards of airworthiness. The twentieth annual report of the Board records that Douglas D.C.-7C aircraft were required to comply with four additional requirements, two involving further equipment. The United States of America also require foreign aircraft to meet their Civil Air Regulations, and the Bristol "Britannia" had done so without alteration or modification. The flight testing activity has increased, and it is claimed of the description of the handling qualities of an aircraft given in the Flight Manuals that, should some feature be below standard, it is so stated in unambiguous terms.

Binding THE ENGINEER

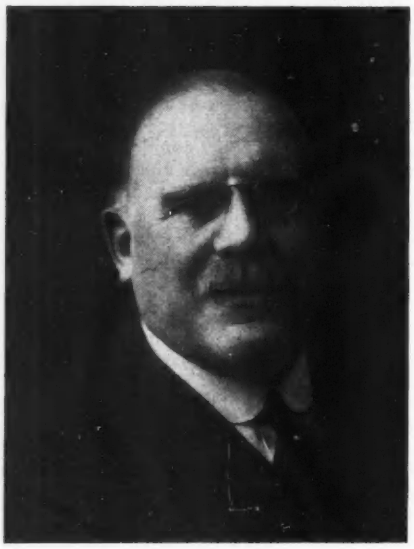
THE attention of librarians and others concerned with binding THE ENGINEER into volume form is drawn to an error that occurred in the numbering of our issue of July 5. On the cover of that issue—and only on the cover—the volume number was printed as 203. It should have been 204. The number was printed as 5294, but should have been 5293. On the first editorial page of the issue the volume number and the issue number are both correctly printed.

Obituary

LORD RIVERDALE, G.B.E., LL.D.

LORD RIVERDALE of Sheffield died at his home at Sheffield last Sunday, July 7. He was eighty-four, and up till a few years ago was chairman and managing director of Arthur Balfour and Co., Ltd., the steel manufacturing firm, which he entered as a youth.

Arthur Balfour, Lord Riverdale, was born in London, and was educated at Ashville College, Harrogate. He began his industrial career in a junior position with his family's steelmaking company, and while still in his 'teens went to America in order to obtain



Lord Riverdale

some general experience of engineering methods in that country. For part of that period he assisted in some research work into metal melting methods and was also concerned with some experiments which, it has been stated, led to the industrial development of electric melting furnaces. A few years later, in 1899, Lord Riverdale set out on a world tour to visit the overseas branches of Arthur Balfour and Co., Ltd., and to open new ones. During the tour he again spent some months in the U.S.A. and visited, among other plants, the Bethlehem Steel Works. There, he studied a new metal-cutting technique. Lord Riverdale's interest in the matter was such that he bought an option on the process for eight weeks. Consultations with some British firms ensued and there then followed some experiments which resulted in the first high-speed steel made in this country.

Lord Riverdale's distinguished career in the Sheffield steel industry was combined with an outstanding record of public services. At the turn of the century he was Vice-Consul for Denmark in Sheffield, and for the two years 1911 and 1912 he was elected Master Cutler. Just prior to the first world war Lord Riverdale served as a member of the Royal Commission on Railways. Inevitably, during the war years, Lord Riverdale was called upon for many services. Throughout the whole of the first world war he was a member of the Treasury's industry advisory committee; subsequently, he was appointed to the advisory council for scientific and industrial research, to the engineering industries committee, and to Lord Balfour's committee on commercial and industrial policy. At the end of the war, Lord Riverdale was elected president of the Sheffield Chamber of Commerce and in 1923 became president of the Association of British Chambers of Commerce. In the same year he was appointed to the advisory council of the Department of Overseas Trade and to the advisory council of the Board of Trade. A year later, Lord Riverdale was invited to take yet another important task when he became chairman of a Government committee on industry and trade. The final report of that committee appeared in 1929 and was a thoroughly detailed document in nine sections dealing with just about every aspect of British industry in the years which followed the post-war boom. In recognition of his work on this committee and in many other spheres of public service, Lord Riverdale was created a baronet in 1929, having been made a K.B.E. six years earlier. He was elected to the peerage in 1935, and was created G.B.E. in 1942.

We have mentioned but a few of the important offices held by Lord Riverdale. There were numerous others, including the chairmanship of a United Kingdom Trade Mission to Egypt in 1931, and membership of the grand council of the Federation of British Industries and of the council of the Machine Tool Trades Association. He became chairman of the Advisory Committee of the Privy Council for Scientific and Economic Research in 1937, and subsequently headed the British Air Mission to Canada. Another interest of Lord Riverdale was the work of the British Council; he was appointed vice-chairman in 1935 and served as president from 1947 to 1950. Then, too, Lord Riverdale took an active part in encouraging the formation of the Production Engineering Research Association; when that body was established in 1946 he became its first president. Finally, reference must be made to Lord Riverdale's work, throughout the second world war and subsequently, for the Royal Air Force Benevolent Fund; he was chairman of the committee of management for several years.

VISCOUNT CHERWELL, C.H., F.R.S.

VISCOUNT CHERWELL, whose death occurred at Oxford on Wednesday, July 3, will long be remembered by his outstanding services to this country during the second world war as scientific adviser to the Prime Minister, Sir Winston Churchill. He was for many years Professor of Experimental Philosophy in the University of Oxford, and for the greater part of that time was well known as Professor F. A. Lindemann.

Frederick Alexander Lindemann was born at Baden-Baden in April 1886. His father was an engineer who subsequently settled in this country and became a British citizen. F. A. Lindemann was the younger son; he was educated at Darmstadt and at Berlin University where he studied under Rubens, Planck and Nernst, gaining a Ph.D. degree in 1910. One of his special studies was concerned with the physical significance of the quantum theory, and after leaving Berlin University, Lindemann went to Paris to continue his research and experimental work along this and other lines. By the time of the first world war Lindemann's work had already secured a place of importance. He was appointed director of the Royal Air Force physical laboratory at Farnborough, and contributed much, both in the laboratory and as an experimental pilot, to the successful development of the military aircraft produced by this country in the 1914-18 war.

Early in 1919, F. A. Lindemann was invited to take the chair of experimental philosophy at Oxford University, and associated with it was a Fellowship of Wadham College. In the following year he was elected a Fellow of the Royal Society. During these inter-war years, Lindemann took a large part in the building and equipping of the new Clarendon Laboratory. The laboratory, it may be recalled, was completed in 1939.

When Sir Winston took office as Prime Minister in 1940, Professor Lindemann became his personal assistant. Shortly afterwards he was raised to the peerage, taking the title of Baron Cherwell of Oxford, and in 1942 was appointed Paymaster-General with Cabinet rank. He retained that office until the end of the war, and was again appointed to it when Sir Winston became Prime Minister for the second time. Lord Cherwell was untiring in his efforts to emphasise to the Government and to the country the importance of scientific research. His speeches in the House of Lords were not frequent, but they were always forthright. In a debate in July 1943, for example, Lord Cherwell made it plain that the importance of fostering pure fundamental research could never be over-rated. That was a fact, he said, which had been more widely recognised abroad than in this country. Many great firms abroad, Lord Cherwell continued, maintained magnificent research laboratories in which men of the greatest distinction were proud to work. In this country, he then observed, we had "not yet quite reached that level of enlightenment." There can be little doubt that such utterances have proved valuable to the extension of research facilities in the post war years.

Lord Cherwell was appointed to the United Kingdom Atomic Energy Authority in 1954. Two years later, he retired from his chair at Oxford, having then reached the age of seventy. He was made a Companion of Honour in 1953 and a Viscount last year.

MAJOR W. G. WILSON, C.M.G.

THE death occurred on Sunday, June 30, of Major W. G. Wilson, C.M.G., B.A., M.I.C.E., M.I.Mech.E. Walter Gordon Wilson was born in 1874 and educated in H.M.S. "Britannia" and at King's College, Cambridge. In the early years of this century he took part in the design and manufacture of the Wilson and Pilcher car, which was notable for a particularly advanced transmission. Four ratios were obtained from a pair of epicyclic gears of different ratios, even as in the "Hydramatic" transmission, which has enjoyed decades of success in the U.S.A. The two planetary units were driven respectively by the sun wheel and the annulus and were therefore able to utilise many similar parts despite their differing ratios. The gear engaging clutches were operated by the driver through a single lever. Forward or reverse were selected on the final drive. During the first world war he participated in the construction of the prototype British armoured fighting vehicle or "tank." For his services in the war Major Wilson was granted £10,000 and appointed Companion of the Order of St. Michael and St. George. The gearbox which to-day bears his name incorporates a different principle, having one epicyclic for every indirect ratio, although compounding in the original manner is used to obtain a full eight speeds. Self-Changing Gears, Ltd., was founded by Major Wilson, and has produced gearboxes not only for automobiles but also for rail vehicles and motor vessels.

Minor Losses in Metering Nozzles

By T. H. REDDING, M.Sc., F.Inst.P., A.M.I.Mech.E.*

(No. II—*Continued from page 7, July 5*)

An extended one-dimensional study of converging flow in closed channels leads to a general equation for the pressure drop versus (bulk) flow-rate relationship. This is sufficiently comprehensive to indicate the trends of variation of the value of the flow coefficient with respect to many possible variations in the flow conditions (both upstream of and within the convergence itself) which are not ordinarily taken into account in more elementary treatments of the subject. Following a comparative study of the geometry and flow-characteristics of two series of parallel-throated nozzles used for metering (A.S.M.E. and I.S.O. metering nozzles) the above equation is used to evaluate and discuss probable values for the minor energy-loss factors (or so-called "minor losses"), which define the extent to which irreversible work is done by the fluid in the course of its passage through the nozzle. These evaluations reveal systematic but opposite tendencies in the manner in which the respective (A.S.M.E. and I.S.O.) minor losses vary with the throttle (area) reduction-ratio, and are shown to be such as to substantiate known (or probable) characteristic features of the flow patterns, as have been determined (or inferred) from other experimental and theoretical studies in this field.

General Equation of Flow : Derivation of the Energy Loss Factor E

CONSIDERING the problem of flow through a parallel-throated (pipe) nozzle in its most general form—in which the fluid boundary at every point within and external to the nozzle does not necessarily coincide with the contour of the channel walls—we refer to the definition sketch of Fig. 9 (*a*) and define a set of working parameters as follows :—

D = main diameter (i.e. diameter of the unobstructed channel).

$A=\frac{\pi D^2}{4}$ = cross-sectional area of main.

d = diameter of the nozzle throat and of the (cylindrical) exit piece.

$a=\frac{\pi d^2}{4}$ = cross-sectional area of nozzle throat and exit piece.

$m=a/A=d^2/D^2$ = nozzle area-reduction ratio.

G = bulk mass rate of flow.

Q = bulk volumetric rate of flow.

$V=Q/A$ = (geometrical) bulk pipe velocity.

γ = fluid density (assumed independent of pressure).

η = fluid (dynamic) viscosity.

$R_D=\frac{VD}{\eta/\gamma}=$ Reynolds number of the flow, calculated with reference to the pipe diameter D.

$R_d=\frac{Vd}{\eta/\gamma}=$ Reynolds number of the flow calculated with reference to the nozzle-throat diameter d.

[Thus, $R_d=\sqrt{m}R_D$.]

We now identify normal channel sections A_1 and A_2 at distances a_1 and a_2 upstream and downstream of the nozzle entrance section (A_{10}) except that channel sections downstream of the nozzle-entrance section (A_{10}), but upstream of the nozzle-exit section (A_{2e}) will refer to nozzle sections only, i.e. the "dead water" in the re-entrant between the nozzle and the pipe wall is not considered part of the fluid stream.

Further, assuming the general case where curvature of the stream lines is apparent (due either to curvature of the channel walls and/or the incidence of separation), we define stream surfaces S_1 and S_2 as being surfaces whose normals at every point coincide with the local (i.e. time averaged) direction of flow and whose perimeters coincide with those of the sections A_1' and A_2', where these latter areas are those portions of A_1 and A_2 over which the fluid velocity is greater than zero. Thus, were we dealing with the ideal case of irrotational flow of an inviscous fluid, S_1 and S_2 would concide with the velocity-potential surfaces. Again, if no separation occurs A' coincides with A_1, whilst, with no curvature of the stream lines, S_1 coincides with A_1' : similar remarks apply to the sections A_2, A_2' and S_2 (see Fig. 9(*a*)).

Anticipating no confusion to be involved by using the same symbol for the identification of a pipe or stream section and the actual area thereof, we put

$$\theta_1=\frac{S_1}{A_1'} \quad . \quad . \quad . \quad . \quad . \quad (1.1)$$

$$\theta_2=\frac{S_2}{A_2'} \quad . \quad . \quad . \quad . \quad . \quad (1.2)$$

$$\mu_1=\frac{A_1'}{A_1} \quad . \quad . \quad . \quad . \quad . \quad (2.1)$$

$$\mu_2=\frac{A_2'}{A_2} \quad . \quad . \quad . \quad . \quad . \quad (2.2)$$

$$V_1=\frac{Q_1}{S_1} \quad . \quad . \quad . \quad . \quad . \quad (3.1)$$

$$V_2=\frac{Q_2}{S_2} \quad . \quad . \quad . \quad . \quad . \quad (3.2)$$

noticing that

$$A_1=A_2 \quad \text{(except between sections } A_{10} \text{ and } A_{2e}) \quad . \quad (4)$$

$$\theta_1\mu_1=\frac{S_1}{A_1} \quad . \quad . \quad . \quad . \quad . \quad (5.1)$$

$$\theta_2\mu_2=\frac{S_2}{A_2} \quad . \quad . \quad . \quad . \quad . \quad (5.2)$$

$$\frac{S_2}{S_1}=\frac{\theta_2\mu_2}{\theta_1\mu_1}m \quad . \quad . \quad . \quad . \quad (6)$$

When no separation occurs

$$\mu_1=\mu_2=1 \quad . \quad . \quad . \quad . \quad (7)$$

$$\theta_1=\frac{S_1}{A_1} \quad . \quad . \quad . \quad . \quad . \quad (8.1)$$

$$\theta_2=\frac{S_2}{A_2} \quad . \quad . \quad . \quad . \quad . \quad (8.2)$$

and when, in addition, no curvature of the stream lines is apparent,

$$\mu_1=\mu_2=1 \quad . \quad . \quad . \quad . \quad (7)$$

$$\theta_1=\theta_2=1 \quad . \quad . \quad . \quad . \quad (9)$$

$$S_1=A_1 \quad . \quad . \quad . \quad . \quad . \quad (10.1)$$

$$S_2=A_2 \quad . \quad . \quad . \quad . \quad . \quad (10.2)$$

Finally, in the subsequent analysis the need to refer to the variation of local fluid velocity and pressure over any given stream surface will necessitate the introduction of so-called "correction" coefficients, defined as follows :—

$$C_1=\frac{\int w_1^2 dG}{G}\Big/V_1^2 \quad . \quad . \quad . \quad . \quad . \quad (11.1)$$

$$C_2=\frac{\int w_2^2 dG}{G}\Big/V_2^2 \quad . \quad . \quad . \quad . \quad . \quad (11.2)$$

$$Y_1=\frac{\int(P_1-p_1)dG}{G}\Big/(P_1-P_2) \quad . \quad . \quad (12.1)$$

$$Y_2=\frac{\int(P_2-p_2)dG}{G}\Big/(P_1-P_2) \quad . \quad . \quad (12.2)$$

where w_1 and p_1 are local values of the fluid velocity and pressure over an elemental area dS_1 (of the stream area S_1), which determines an elemental stream tube carrying a mass throughput dG (see Fig. 9(*b*)). P_1 is wall pressure at periphery of pipe section A_1, w_2, p_2 and P_2 are terms of similar meaning defined with reference to the stream and pipe sections S_2 and A_2 respectively.

The factor C, as defined above, is the so-called kinetic energy correction factor, the value of which, for turbulent flow in closed circuits, is usually not very different

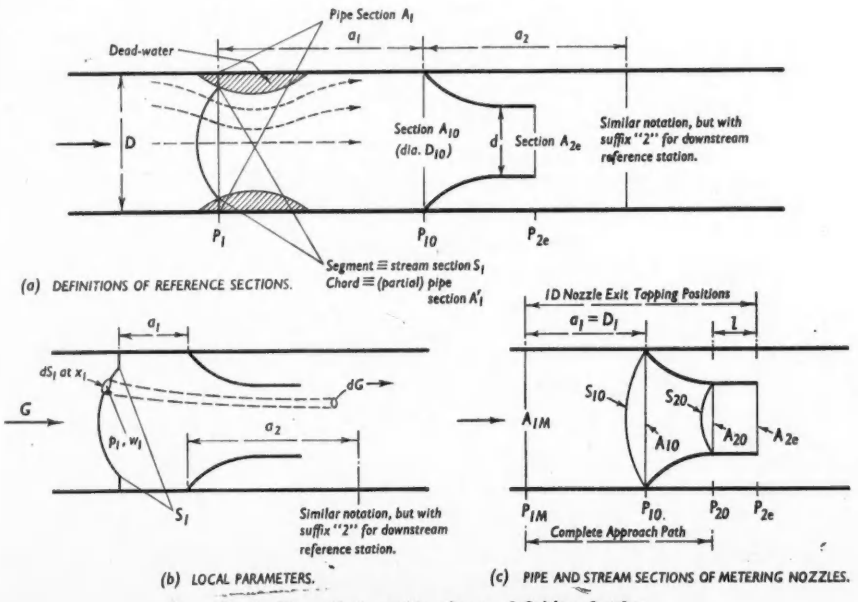
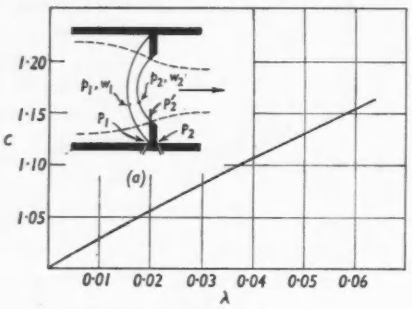


Fig. 9—Theoretical considerations : definition sketches

* British Scientific Instrument Research Association.

from unity, e.g. for fully developed turbulent flow in pipes of circular cross section $C=1\cdot05$ at $R=10^5$. However, under certain circumstances its value can rise appreciably, as, for example, in the case of fully developed viscous flow, where for pipes of circular cross section the characteristic parabolic velocity profile gives rise to the value $C=2\cdot0$. For fully developed turbulent flow, Engel and Davis[15] have evaluated C as a function of the resistance coefficient λ †† (and thus of the Reynolds number), and reference to this relationship will frequently be made in the discussion which follows. The form of relationship (after Engel and Davis) is shown in Fig. 10, and a summary of the relevant theoretical considerations given in Appendix I.

[In dealing with cases where separation occurs, some measure of simplification (*not* however, adopted in this article) can be effected by defining C_1 and C_2 by the equations $C_1=\dfrac{\int w_1^2 dG}{G}\Big/V_1^2$, and $C_2=\dfrac{\int w_2^2 dG}{G}\Big/V_2^2$; where the surface integrals (and the velocities V_1 and V_2) are taken with respect to the composite surface composed of the previously specified stream surfaces (S_1 and S_2), together with the normal cross-sectional areas of the "dead water" layers (lying within the pipe-reference sections A_1 and A_2),



C≡kinetic energy correction factor.
λ≡resistance coefficient.
C versus λ, after Engel and Davis (see reference 15).

Fig. 10—Flow in smooth pipes: characteristic C versus λ

and over which we can assume $w_1=w_2=0$. There would now be no need to introduce contraction coefficients μ_1 and μ_2, since the effect of the stream contraction is included in the kinetic energy correction factors C_1 and C_2—in fact, this rather more general method of treatment could, conceivably, take into account not only zones of zero velocity, but also zones subject to backflow (i.e. flow in a direction reverse to that of the main stream). The disadvantage of the method, however, is its tendency to mask the physical aspects of the problem within the somewhat simplified mathematics. Thus, unfamiliar values for the kinetic energy correction factor are introduced which result in the lessening of the facility with which we recognise, without formal calculation, the deviation of the velocity profile from a given norm (when a value for the extent of separation is known from experiment, or from other theoretical considerations of the problem). Also, it would not be reasonable to anticipate continuous and relatively gradual changes in C_1 and C_2 (as is the case when these quantities are defined with respect to stream surfaces) or to expect that their range of variation remains sensibly the same as that associated with flow in which no separation takes place.]

The factor Y in a region of parallel stream lines can safely be assumed equal to unity, but for stream sections carrying curved stream lines may differ considerably from this value. If we concede that the potential flow pattern is, at least, an approximation to the actual flow conditions, it would appear that the potential surface which originates from the corner formed between the entrance section of a pipe nozzle (with $D_0<D$) or of a pipe orifice plate and the pipe wall itself, is a case in point of $Y=1$. Here, in the corner, stagnation occurs and the pressure rises by an amount equal to the impact pressure of the main stream (i.e. by $\Delta P=\frac{1}{2}\gamma G^2/\pi^2 D^4$), whilst at the point of intersection of the axis and the potential surface in question the axial pressure has already commenced to fall; in the case of a pipe orifice with $m=0\cdot35$, an approximate integration over this (corner) potential surface—as determined from data emanating from a rheo-electrical investigation[16] on flow through nozzles—gives $Y_1=0\cdot09$.

To a degree, in that the integration of w is taken over stream surfaces rather than over pipe sections, the above definitions of C_1 and C_2 differ from those usually given in (extended) one-dimensional treatments of the subject which attempt to take into account the distribution of velocity over the reference sections; however, C_1 and C_2 assume their conventional values when neither separation nor stream-line curvature occurs, since under these circumstances stream surfaces become identical with the pipe sections themselves. In addition, the above analysis introduces terms (Y_1 and Y_2), which take into account the effect of non-uniform pressure distribution over the (same) stream surfaces. The object of introducing the stream surfaces, and using these as reference surfaces—in preference to corresponding pipe sections—is that over such surfaces the conceptions of general velocity of flow and total pressure retain their simple physical significance even in regions of rapidly converging stream lines. Thus, the volumetric rate of flow is still given by the flux of the velocity vector over the reference surface and the static pressure at any point refers to that registered by a probe whose entrance section is disposed perpendicular to the reference surface at the point in question, i.e. co-planar with the local stream line.

Both algebraically, and from the point of view of physical concept, the use of the factors C_1, C_2, Y_1 and Y_2 (defined with respect to the stream surfaces) permits the simplest derivation of a general equation governing the behaviour of converging flow under conditions in which both stream-line curvature and separation take place. However, it would be quite incorrect to assume that this represents the only rational method of dealing with the existence of velocity profile, stream-line curvature and separation phenomena, or that it is, necessarily, the best method of treatment in every case. Thus, in deriving an equation to relate the flow rate to the rise in wall pressure ΔP which occurs immediately upstream of a pipe metering throttle (i.e. the so-called "plate" impact pressure) Engel and Davis [15] introduce a term β (evaluated from a knowledge of the velocity profile in uniform pipe flow, which is assumed to prevail at a distance $1D$ upstream of the throttling device) and a constant of proportionality K, and from considerations of momentum transfer derive the simple relationship $V_1^2=\Delta P/\gamma\beta K$. The merit of this method of treatment is that it does not require knowledge of C_1 and Y_1—quantities which, in the presence of the very steeply curved stream lines immediately upstream of the nozzle, are probably indeterminate: i.e. they cannot be assessed theoretically and direct experimental determinations, if not impossible, would be extremely difficult to carry out. The fact that this method of treatment is unsuitable for presenting the generalised one-dimensional theory of closed channel flow is really of little importance, since the very feature of the plate-impact-pressure problem which renders formulæ developed from considerations of energy transfer of little practical use (i.e. the very steep curvature of the stream lines in the immediate upstream vicinity of a metering throttle) is also that which facilitates its treatment from the point of view of considerations of momentum transfer.

With the above notation, and using absolute units, we apply Bernouilli's theorem, as relating to incompressible flow, to the elemental stream tube passing through points x_1 and x_2 on the upstream and downstream reference (stream) surfaces S_1 and S_2 respectively, to give

$$\frac{w_2^2}{2}-\frac{w_1^2}{2}=\int_{p_2}^{p_1}\frac{1}{\gamma}dp-z \quad . \quad . \quad . \quad (13)$$

where z is the irreversible work done (by frictional forces) per unit mass of fluid during its transfer from x_1 to x_2 via the path of the aforementioned elemental stream tube.

Conveniently, equation (13) can be written the form

$$\int_{(2)}\frac{w_2^2}{2}\frac{dG}{G}-\int_{(1)}\frac{w_1^2}{2}\frac{dG}{G}=\int_{(1)}\frac{1}{\gamma}p_1\frac{dG}{G}-\int_{(2)}\frac{1}{\gamma}p_2\frac{dG}{G}-\int z\frac{dG}{G} \quad . \quad . \quad . \quad . \quad . \quad (14)$$

where suffixes (1) and (2) imply that integration is taken over the stream surfaces S_1 and S_2 respectively.

In terms of the quantities C_1, C_2, Y_1 and Y_2 [as defined by (11.1), (11.2), (12.1) and (12.2) respectively], equation (14) can be written in the form

$$C_2\frac{V_2^2}{2}-C_1\frac{V_1^2}{2}=\frac{1}{\gamma}[P_1-Y_1(P_1-P_2)]-\frac{1}{\gamma}[P_2-Y_2(P_1-P_2)]-Z \quad . \quad . \quad . \quad . \quad . \quad (15)$$

i.e.

$$C_2\frac{V_2^2}{2}-C_1\frac{V_1^2}{2}=\frac{1}{\gamma}(P_1-P_2)[1-(Y_1-Y_2)]-Z \quad . \quad . \quad . \quad . \quad . \quad (16)$$

where Z is the total work done by friction per unit mass of fluid in its passage from S_1 to S_2.

Furthermore, considerations of (mass) continuity within the elemental stream tube result in the equation

$$w_1dS_1=w_2dS_2 \quad . \quad . \quad . \quad . \quad (17)$$

which integrates to

$$\int_{(1)}w_1dS_1=\int_{(2)}w_2dS_2$$

i.e.

$$V_1=\frac{S_2}{S_1}V_2 \quad . \quad . \quad . \quad . \quad (18)$$

when the elimination of S_2/S_1 between (18) and (6) gives

$$V_1=\frac{\mu_2\theta_2}{\mu_1\theta_1}mV_2 \quad . \quad . \quad . \quad (19)$$

Also:

$$G=\int_{(2)}w_2\gamma dS_2 \quad . \quad . \quad . \quad (20)$$

$$=\gamma S_2V_2. \quad . \quad . \quad . \quad . \quad (21)$$

when S_2 can be eliminated between (21) and (5.2) to give

$$G=(\gamma\theta_2\mu_2A_2)V_2 \quad . \quad . \quad (22)$$

†† As defined by the equation $\frac{dP}{dx}=\lambda\frac{1}{D}\cdot\gamma\frac{V^2}{2}$, where $\frac{dP}{dx}$ is the pressure gradient at the pipe wall.

The requisite flow equation, relating G to (P_1-P_2), now follows immediately by eliminating V_1 and V_2 between equations (16), (19) and (22) to give

$$G=\frac{\theta_2\mu_2A_2}{\sqrt{C_2-C_1\left(\frac{\mu_2\theta_2}{\mu_1\theta_1}\right)^2m^2}}\sqrt{2\gamma(P_1-P_2)[1-(Y_1-Y_2)]-2Z\gamma^2} \quad . \quad . \quad . \quad . \quad . \quad (23)$$

For the purposes of this analysis, it is convenient to write Z‡‡ in the form

$$Z=E\frac{V_2^2}{2} \quad . \quad . \quad . \quad . \quad (24)$$

and to eliminate V_2 and Z between equations (22), (23) and (24) to give

$$G=\frac{\theta_2\mu_2A_2}{\sqrt{C_2-C_1\left(\frac{\mu_2\theta_2}{\mu_1\theta_1}\right)^2m^2+E}}\sqrt{2\gamma(P_1-P_2)[1-(Y_1-Y_2)]} \quad . \quad . \quad . \quad . \quad . \quad (25)$$

From equation (25) it is apparent that G is only proportional to $\sqrt{P_1-P_2}$ when Y_1 and Y_2 are themselves independent of P_1-P_2, or when $[1-(Y_1-Y_2)]$ is proportional to $\sqrt{P_1-P_2}$. However, in practice, this condition appears to be satisfied, even in cases (other than nozzle flow) in which severe curvature of the stream lines and separation of the fluid stream takes place. Thus, for example, in the case of a corner-tapped pipe orifice (see Fig. 10—inset (*a*)), we have steep curvature of the stream lines on the upstream side, and pronounced separation downstream but, nevertheless, experiment shows G as being proportional to $\sqrt{P_1-P_2}$ to within very close limits in so far as incompressible flow is concerned. But this is not surprising if we consider the potential flow pattern to be, at least, a first approximation to actual flow conditions. In this case, in spite of the steep curvature of the potential surface which contains the upstream tap, (P_1-p_1) is proportional to w_1^2, which being sensibly a fixed fraction of the square of the mean velocity is thus (to a first approximation) proportional to (P_1-P_2) ; Y_1 in consequence is independent of (P_1-P_2). Again, the actual flow pattern downstream of the orifice is characterised by severe (fully developed) separation, with the ultimate formation of a vena-contracta. Thus, we may write $P_2-p_2=(P_2-P_2')+(P_2'-p_2)$, where P_2' is the pressure at the surface of separation and P_2 (as before) that at the wall. That (P_2-P_2') is not equal to zero is due to energy absorbed by eddies which persist in the (theoretically) dead-water between the fluid stream and the pipe wall, whilst $(P_2'-p_2)$—due to effect of stream-line curvature—tends to zero as the vena-contracta is approached. If we assume —as is reasonable—that (P_2-P_2') is proportional to (P_1-P_2), and, as before, interpret the potential-flow pattern as implying a proportional relation between $(P_2'-p_2)$ and (P_1-P_2), it follows that Y_2 (like Y_1) is itself independent of P_1-P_2. Thus, upstream and downstream conditions are such as to render G proportional to $\sqrt{P_1-P_2}$.

Finally, if the flow coefficient is defined (conventionally) by the equation

$$\alpha=\frac{G}{A_2\sqrt{2\gamma(P_1-P_2)}} \quad . \quad . \quad . \quad (26)$$

we may eliminate

$$\frac{G}{A_2\sqrt{2\gamma(P_1-P_2)}}$$

between equations (25) and (26) to give

$$\alpha=\frac{\theta_2\mu_2\sqrt{1-(Y_1-Y_2)}}{\sqrt{C_2-C_1\left(\frac{\mu_2\theta_2}{\mu_1\theta_1}\right)^2m^2+E}} \quad . \quad . \quad (27)$$

In the case of throttling devices used for metering purposes, the virtue of this equation lies in its ability to reveal the constitution of the flow coefficient (in terms of C_1, C_2 ; Y_1, Y_2 ; μ_1, μ_2 ; θ_1, θ_2—together with the geometrical factors involved) when the problem is complicated by considerations of velocity profile, stream-line curvature and/or separation at the (reference) sections at whose peripheries the pressure tappings are made. In such cases the general equation is often capable of indicating the trend—if not the extent—of the change in value of the flow coefficient consequent on variation of one or more of the factors which can influence the pattern of the flow.

In its practical applications to analytical problems, however, use of the equation is limited to cases where the factors C_1, C_2, Y_1, Y_2, μ_1, μ_2 and θ_1, θ_2 are known—or to which reasonable values may be ascribed—from other considerations of the problem in hand. In practice this usually reduces to cases in which neither stream-line curvature and/or separation are apparent at the reference sections ; when, with the exception of C_1 and C_2 all the above factors reduce to unity.

Determination of E

An interesting application of the above considerations is the evaluation of the minor losses in A.S.M.E. and I.S.O. metering nozzles when the reference sections are taken at the position of minimum pressure upstream of the nozzle (pipe section A_{1M}) and within the extremity of the throat itself (A_{2e}) (see Fig. 9(*c*)). For A.S.M.E. nozzles minimum pressure upstream of the nozzle occurs at a distance (approximately) $1D$ from the nozzle-entrance section, but for I.S.O. nozzles the corresponding distance appears to be $0{\cdot}7D$, with negligible pressure gradient between the $0{\cdot}7D$ and $1{\cdot}0D$ upstream stations—see Figs. 4 and 7.

At these positions of the pressure taps no separation takes place and the stream lines are straight and parallel : thus, we may put $\theta_1=\mu_1=Y_1=\theta_2=\mu_2=Y_2=1$ and solve equation (27) for E in terms of α, C_1 and C_2, i.e. :

$$\alpha\equiv\alpha_e=\frac{1}{\sqrt{C_{2e}-C_{1M}m^2+E}} \quad . \quad . \quad (28)$$

or

$$E=\frac{1-\alpha_e^2(C_{2e}-C_{1M}m^2)}{\alpha_e^2} \quad . \quad . \quad (29)$$

where α_e is the flow coefficient relevant to pressure tappings taken at peripheries of reference sections A_{1M} and A_{2e} (hereafter generally referred to as "$1D$-nozzle exit" taps), and C_{1M} and C_{2e} the respective kinetic energy correction factors relating to these sections.

In applying equation (29) to the evaluation of E we follow Engel and Davis[15] in assuming C_{1M} to have the same value as for an uninterrupted length of straight pipe. On the other hand, we will assume the velocity profile in the throat at the entrance to the exit piece (pipe section A_{2e}) to be that of a uniform velocity distribution over the section —i.e. as given theoretically (i.e. rheo-electrically) for the case of potential flow,[16] and confirmed experimentally by Nikuradse[21] for real flow through rounded entrances under conditions of zero velocity of approach. This is tantamount to assuming the condition $C_{2e}=1$ at the entrance to the exit piece, a condition which will be assumed to apply also to the nozzle-exit section A_{2e}. This latter assumption is tantamount to assuming only insignificant redevelopment of velocity profile over the short length of exit piece which characterises these devices.

We thus put $C_{2e}=1$, when equations (28) and (29) take the comparatively simple forms

$$\alpha_e=\frac{1}{\sqrt{1-C_{1M}m^2+E}} \quad . \quad . \quad (30)$$

and

$$E=\frac{1-\alpha_e^2(1-C_{1M}m^2)}{\alpha_e^2} \quad . \quad . \quad (31)$$

The friction loss factor E referred to $1D$-nozzle exit pressure taps is localised to the flow path through the nozzle itself, together with a small "pipe" loss between the position of maximum upstream pressure and the nozzle-entrance section ; moreover, E is now established in terms of an experimentally determined flow coefficient α_e and the (upstream) kinetic energy correction factor C_{1M} (as determined by the Reynolds number of the flow).

In general, few direct determinations of α_e§§—with the downstream tapping made into the extremity of the throat itself—have been made. However, probable values of this coefficient can be computed (from a knowledge of the coefficient relating to pipe-wall or corner taps, together with relevant downstream pipe-wall pressure-gradient data) if we assume the pipe-wall pressure at the pipe section containing the nozzle exit to be the same as that in the nozzle-exit section itself. This is particularly the case for the A.S.M.E. nozzle, where the flow coefficient relating to pipe-wall taps has been determined experimentally to a high degree of accuracy and for which the upstream pressure tapping is already situated a distance $1D$ upstream of the nozzle-entrance section. Furthermore, except for large values of the area reduction ratio, the distance between those (downstream) sections which contain the pipe-wall tapping and the nozzle exit is quite small, so that the factor for converting "pipe-wall" coefficients to "$1D$-nozzle exit" coefficients is necessarily very nearly unity.

Energy Loss Factor : Values for A.S.M.E. and I.S.O. Nozzle Forms

A.S.M.E. Nozzles.—Values of E for A.S.M.E. nozzles, calculated according to equation (31) are shown in Fig. 11, E being plotted as a function of the Reynolds number

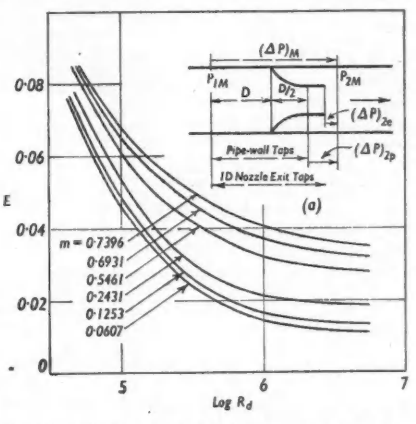


Fig. 11—A.S.M.E. nozzle : E as a function of m and log R_d

‡‡ That we choose to express Z in these units (i.e. in terms of $V_2^2/2$) does not, necessarily, imply any physical significance or specific physical properties to the new factor E—in particular, there is no *ipso facto* reason for assuming that E has the nature of a constant of proportionality.

§§ See reference 4. [In the course of the discussion which follows this paper, it appears that direct determinations of the flow coefficient using "$1D$-nozzle exit" taps are subject to large probable error. This, it is believed, is due to the difficulty of establishing reproducible conditions at a tapping point which connects with a zone of very high velocity, as is often apparent when the downstream tapping is made directly into the wall of the throat itself.]

of the flow (calculated with respect to the nozzle-throat diameter) for selected (constant) values of the area-reduction ratio : these latter were chosen as m=0·0607, 0·1253, 0·2431, 0·5461, 0·6931 and 0·7396—corresponding to those values of m for which directly determined pressure gradient data are available.

The flow coefficient data used in determining these curves is taken from the aforementioned paper by Bean, Beitler and Sprenkle[4] and the requisite (downstream) pressure gradient data from an earlier paper by Bean and Beitler[5] : furthermore, the data used refers to nozzles installed in a 4in diameter main, this value of the pipe diameter being chosen in view of the fact that the most complete and reliable pressure gradient data available refers to mains of this size. However, changes in pipe diameter are not likely to affect E appreciably, since both the flow coefficient appertaining to pipe-wall taps and the downstream wall-pressure gradient are almost independent of the pipe diameter.

The formula used to convert the coefficient relevant to pipe-wall taps (α_p) to those relating to 1D-nozzle exit taps (α_e) follows on eliminating G from the general flow equation as written with respect to these two positions of the pressure taps. The conversion formula is $\alpha_e=\alpha_p\sqrt{(1-K_{2p})/(1-K_{2e})}$, with $K_{2p}=(\Delta P)_{2p}/(\Delta P)_M$ and $K_{2e}=(\Delta P)_{2e}/(\Delta P)_M$; where $(\Delta P)_{2p}$, $(\Delta P)_{2e}$ and $(\Delta P)_M$ are respectively the pressure differences between the (0·5D) downstream " pipe-wall " tap and the minimum downstream pressure, the " nozzle-exit " (downstream) pipe-wall tap and the minimum downstream pressure, and the overall pressure drop between the upstream and downstream stationary (minimum) values of the wall pressure—see Fig. 11 (inset *a*).

N.B.—Upstream pressure gradient data—which is sensitive to tapping-hole diameter—does not enter these calculations, since α_p refers to tappings in which the upstream tapping is already in the 1D-upstream position.

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(To be continued)

Belgian Mail Steamers

By G. W. TRIPP, O.B.E., F.C.G.I., M.I.C.E.

NOW that new passenger vessels are being built for the mail services between Ostend and Dover, it would seem to be an appropriate time to review the position, and the developments that have taken place in the ships employed. In view of the fact that the sea passage is considerably longer than those between Dover and Calais and Folkestone and Boulogne, an attempt has been made to meet this competition by placing faster ships on the Belgian service, with a result that for many years they have been among the fastest cross-Channel mail steamers.

The service is an old-established one, for in 1846 it was decided that the Belgian State should operate a steamer service to work in conjunction with the railways, this being sixteen years before authorisation was given to the railways of Britain to own and operate steamships. These early steamers were given names that would become household words in Belgium. The first " Marie Henriette " may be taken as typical. She was an iron paddle steamer having a length of 200ft, breadth of 24·8ft, depth 13·9ft, and with two oscillating cylinders 58in diameter, and a stroke of 54in, and a boiler pressure of 30 lb per square inch. She was able to reach a speed of about 16 knots. She was built in 1869 and continued in service until 1893. Between 1869 and 1896 thirteen paddle steamers were built, of which " Leopold II " (Fig. 2) was reputed to be the fastest cross-Channel steamer. She was the last steamer to be built by William Denny and Bros., of Dumbarton, all subsequent steamers coming from Cockerill's yard. Her principal dimensions were : length, 340ft ; breadth, 38ft ; depth, 15ft ; tonnage 1367 gross. She was driven by compound diagonal engines, the two cylinders having a diameter of 59in and 104in respectively with a stroke of 81in, which gave her a speed of 22 knots.

As was the case with the British railway steamers plying in these waters, no screw-propelled steamers driven by reciprocating engines were built, the transition from paddle to screw was to steamers driven by turbines. The much maligned South Eastern and Chatham Railway was the first to have built a turbine steamer, the celebrated " The Queen," built in Denny's yard, coming into service in 1903. Two years later the Belgian turbine steamer " Princesse Elizabeth " appeared, her triple screws being driven direct by steam turbine. She was slightly larger than her English rivals, her leading dimensions being : length, 357ft ; breadth, 40ft ; depth, 23·2ft ; tonnage, 1747 gross. She attained a speed of well over 24 knots. For practically thirty years the turbine steamer was unassailed and in all ten steamers were built, all coming from Cockerill's yard. The last five were twin-screw, single-reduction-geared turbine steamers, among the finest of their class, and all of a speed of upwards of 23 knots. " Prince Charles " (Fig. 3) may be taken as typical of the class. Built in 1930, she had a length of 347ft ; breadth, 46·2ft ; depth, 22·8ft ; tonnage, 3088 gross.

In 1934 an entirely new departure was made by the introduction of a motor vessel for cross-Channel work of the nature required. The first motor vessels to be used for cross-Channel were admittedly those of the Belfast Steamship Company for service between Liverpool and Belfast, the sailings being by night, when high speed was not necessary. " Prince Baudouin," (Fig. 4), however, was to take her place on a highly competitive service, where, as has been pointed out, high speed is essential. She was revolutionary in many ways : her very appearance was unorthodox, for her two masts and squat funnel were without the least rake, which seemed to indicate a slow speed, she was larger than any of her turbine sisters, and was provided with superior sheltered accommodation for passengers. Her leading dimensions are length, 357ft ; breadth, 49·2ft ; depth, 22·4ft ; tonnage, 3570 gross. She is driven by twin screws coupled to two-stroke cycle single-acting oil engines, each having twelve cylinders, 22$\frac{13}{16}$in in diameter and a stroke of 33$\frac{1}{16}$in. On her trials a speed of 25$\frac{1}{4}$ knots was obtained, making her easily the fastest diesel-driven ship. She has many features, novel at the time she came into service ; her foghorn is placed on the mast, large shelter decks are provided with specially thick and treated glass, and special absorbent materials are

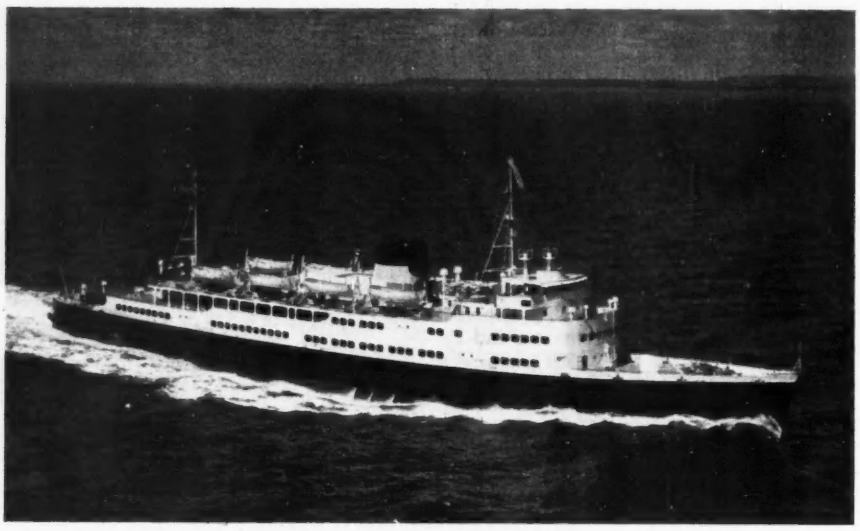


Fig. 1—" Roi Leopold III " (1956)

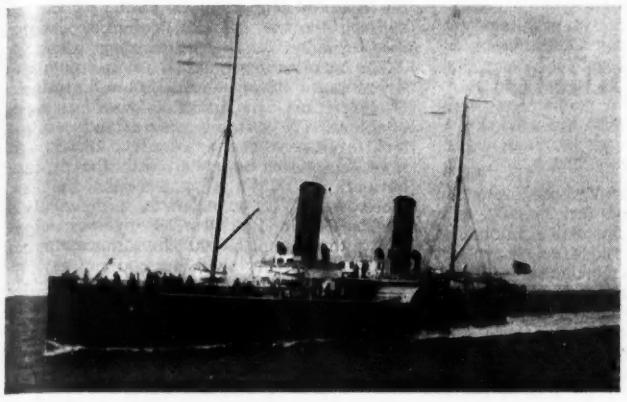


Fig. 2—Belgian mail steamer " Leopold II " approaching Dover (1892)

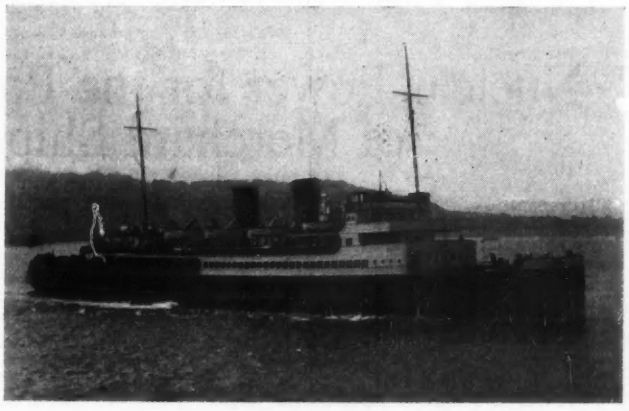


Fig. 3—" Prince Charles " leaving Dover (1930)

used with the aim of obviating noise.

So satisfied were her owners with the new vessel that in 1937 a second vessel, " Prince Albert," came into service. She was very similar to her sister, but with a slightly greater speed, for she attained 25½ knots on trial. From that time onwards, when further tonnage has been required, motor vessels have been built. One advantage of these motor vessels is that they can go at full speed astern, which proves useful as normally they reverse and come into harbour travelling astern.

After the second world war the services were gradually restored, and it is interesting to note that, in 1948, 264,840 passengers were carried, and year by year the number has steadily increased so that in 1955 the number had gone up to 816,995. At the same time the number of cars, caravans, &c., showed a definite increase, with the result that the Belgian State Administration decided to replace the thirty-six-year-old " London-Istanbul," which had been converted to a car ferry. On September 18, 1948, the new vessel " Prinses Josephine-Charlotte " was launched at the Cockerill shipyard at Hoboken, and she came into service in 1948. Her principal dimensions are : length, 373ft ; breadth moulded, 49ft ; depth to shelter deck, 28¾ft. Cars can be driven on and off by means of the mobile ramp at Ostend, whatever the state of the tide. The garage on board is high enough to accommodate motor coaches and lorries up to 10 tons in weight. There is room for approximately 110 cars. There is accommodation for 700 passengers, for which there are eighteen two-berth cabins and eight four-berth cabins, and there is a restaurant which can seat ninety people. The vessel is propelled by Sulzer two-stroke, single-acting engines, which, with a total power of 8360 h.p. at 320 r.p.m., give the vessel a speed of 22 knots.

When the " Prinses Astrid " was lost in 1949 it was decided to replace her, and in view of the increasing number of passengers and the proposed International Exhibition in Brussels next year, as well as the fact that some of the vessels are ageing, three new large and fast passenger motor vessels were ordered, the first of which, "Roi Léopold III" (Fig. 1), is already in service. The names of the other two vessels will be " Koningin Elisabeth " and " Reine Astrid," both of the same dimensions as their sister, that is : length, overall, 373ft 9in ; breadth, 46ft 7in ; loaded draught, 12ft 6½in ; displacement, 2900 tons ; tonnage, 3794 gross ; horsepower, 15,000 h.p. As will be seen from the illustration (Fig. 1) the vessel is well proportioned, having two tripod masts and one large funnel, so constructed to prevent exhaust fumes coming on deck. The general arrangement is as follows. On the bridge deck is found the wheelhouse in which are all the recognised aids to navigation, and immediately above it are two radar scanners. Below it is the boat deck with a well-equipped wireless room towards the bows. On deck " B " in the bows is a spacious verandah, astern of which is a cabin de luxe, then come toilets, and well astern a large second-class bar. Descending to the next deck (" C ") forward is the purser's office, followed by the second-class entrance hall, and astern of this the first-class restaurant. On the next deck (" D ") are ladies' cabins, and further astern beyond the engine-room the kitchen and pantry, followed by a large garage for cars, another being situated immediately below on " E " deck, where, in addition to the engine-room amidships, there is a ladies' second-class room in front of the garage, and in the bows a first-class gentlemen's saloon. Such is the general layout of the ship. The two restaurants can serve 210 meals simultaneously, there is a seating capacity of 56 in the smoking room, and, in addition to four saloons with berths for 100 passengers, and eighteen two-berth cabins, there is accommodation on the promenade deck for 1200 deck chairs. The carrying capacity of " Roi Léopold III " is 1700 passengers.

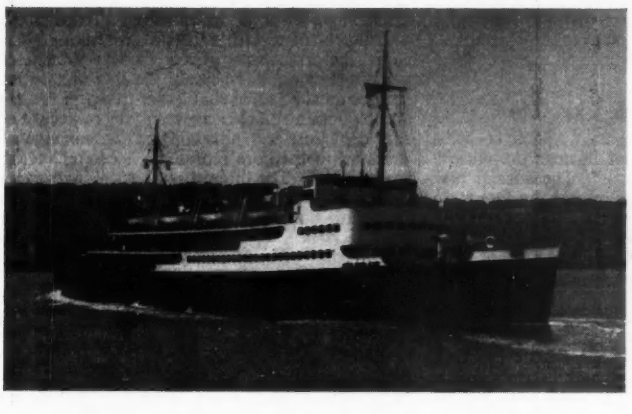


Fig. 4—" Prince Baudouin," the first motor vessel (1934)

There are two twelve-cylinder, two-stroke, single-acting engines, each cylinder having a diameter of 580mm and a stroke of 840mm. At 258 r.p.m. the horsepower is 7500 for each of the two sets, and at 268 r.p.m. the horsepower developed is 8500. The speed of the vessel is 23½ knots. The auxiliary machinery consists of three units, each of 240 h.p. at 500 r.p.m. There is also an emergency unit of 80kW, the primary function of which is use in harbour. To comply with the 1948 International Agreement for the Safety of Human Life at Sea, the following improvements have been made :—(1) Watertight compartments are now created by eleven partitions ; (2) to cope effectively with fire the ship is divided into four sections insulated by partitions, and (3) provision is made for 480 in the eight lifeboats, as against the 440 on the former ships. Rafts with aluminium floaters are provided to accommodate the total number of persons on board, plus 10 per cent. The watertight doors can be closed on the bridge.

It might be mentioned that in the construction of the hull welding has been used to a greater extent than formerly, but where joints are subject to shear riveting is still employed. Every effort has been made to eliminate, or at least to minimise, vibration, one of the great troubles of the motorship from the point of view of the passenger, and certainly this new vessel is better in that respect than her predecessors. An experimental apparatus to deal with the flora and fauna that so rapidly accumulate on the hulls of vessels, materially reducing their speed, has been fitted on " Roi Léopold III," while for the first time stabilisers are to be fitted to the last of the trio, " Reine Astrid." An entire change has been made in the decoration of the passenger quarters, in that a contemporary style has been adopted, and all the equipment is modern.

When the three new vessels are in commission the Belgian Railways and Marine will possess a fleet of cross-Channel mail boats second to none.

LARGE TOWER CRANE.—A rotary tower crane has been added to the range of cranes sold by Abelson and Co. (Engineers), Ltd., of Sheldon, Birmingham. The new crane—the " Buildmaster Model 450 "—has a mast 130ft high and a jib 98ft 6in long. The range of lifting duties is from 4 tons at 32ft 9in radius at a height of 195ft 3in to 1½ tons at 100ft radius at a height of 123ft 6in. The main mast members are of box section with tubular bracings, with the aim of giving added strength without increasing the projected wind surface area. There are hydraulically operated, electrically motivated brakes on the hoist and luffing motions, and a travelling carriage which not only enables the width of the crane to be reduced for transport, but also permits the crane when erected to negotiate tighter curves.

Nuclear Power for the Propulsion of Merchant Ships

THIS paper, which concluded the technical session at the centenary meeting of The Institution of Engineers and Shipbuilders in Scotland, is based on studies carried out by the British Shipbuilding Research Association and was presented by S. L. Smith, D.Sc. (Eng.), and J. E. Richards, B.Sc. (Eng.), Ph.D. A review is given of nuclear fuels, fuel costs and types of reactor available, and the paper then considers the prospects for the commercial application of nuclear power to ship propulsion. The results are recorded of a study made of the permissible cost for a tanker of 47,000 tons deadweight and consideration given to the engineering problems and safety precautions. An abstract of the paper is printed below.

Supply of Nuclear Fuel

In this country we are at an early stage in the development of useful power from nuclear energy. The basic material in which we are interested for providing nuclear power is natural uranium, which contains only 0·7 per cent of the fissile isotope uranium-235, the remainder being uranium-238. The low concentration of nuclear fuel in this material creates problems in reactor design which can be eased if the uranium is enriched in 235 content, but the enriching process is expensive. However, the wide application of nuclear power to marine propulsion is unlikely to be achieved without the use of enriched uranium.

In the United States the first step in power reactor development was the pressurised water reactor, using enriched fuel, installed in the submarine "Nautilus." In this country it was the gas-cooled graphite-moderated natural uranium reactor at Calder Hall, built primarily for the production of military plutonium. The United States is prepared to sell enriched fuel to overseas countries at a price which corresponds roughly to the cost of natural uranium plus about £6 for each gramme (£2700 per pound) of added uranium-235.

Nuclear Fuel Cycles and Costs

All the reactors with which we shall be concerned in this discussion of nuclear propulsion are called "thermal reactors." The nuclear fuel is the 235 isotope of uranium and the fuel rods are of natural uranium or uranium enriched in the 235 isotope. Fission of the nuclear fuel produces heat, fission products and a number of fast neutrons. The fission products are radioactive and the fuel is canned to prevent their escape into the coolant stream which removes the heat generated. The fast neutrons are slowed down in the moderator to thermal energies and cause further fission, thus maintaining the chain reaction. Some of the neutrons are captured by the uranium-238 to form plutonium, a secondary fuel, a small percentage of which is burnt as the reaction continues. Eventually it is necessary to withdraw the fuel elements due to loss of reactivity or because of metallurgical limitations, and the remainder of the plutonium is removed from the spent fuel elements by chemical processing.

In the operation of the natural uranium power reactors which are being built in this country it is hoped that about 3000MW-days of heat will be extracted from each ton of uranium before the fuel elements are removed from the reactor. Although the cycle of operations leads to only about three-sevenths of the fuel being consumed, the direct fuel cost on the basis of 3000MW of heat per ton of uranium is only about 0·2d. per shaft horsepower-hour, about half that of a modern oil-fired installation. The direct fuel cost also depends on the credit given for the plutonium produced.

Because of the high cost of enriched fuel a more complex cycle of operations is necessary when this is used. There is no indication that the direct fuel cost would be any lower than for a natural uranium-fuelled reactor, because of the high cost of fabrication, chemical processing and enriching. When enriched fuel is used it is possible to build in an appreciable amount of excess reactivity and to consider fuel elements of uranium in other than the metallic state. Types of fuel element can be used which will withstand a large burn-up of uranium-235 and in this way chemical processing and fabrication charges per unit heat output are reduced. In a recent American design of pressurised water reactor using enriched uranium oxide fuel pellets in stainless steel cans, it is estimated that it will be possible to extract 8000MW-days of heat per ton of uranium before the fuel elements are withdrawn. While the use of enriched fuel does not appear at the present time to lead to lower direct fuel costs than with natural uranium, it does permit a wide range of reactors to be considered and more robust fuel elements.

As it is unlikely that wide application of nuclear power to marine propulsion can be achieved without the use of enriched uranium, the possible way in which such systems will be developed in this country is a matter of some importance. Appreciable quantities of plutonium will be produced as a by-product from the natural uranium reactors and it is anticipated that this fuel might be used for the enrichment of natural uranium for advanced types of reactor. This plutonium will not begin to be available in quantity until about 1965 and both the method and economics of its use are not yet clear.

Theoretical studies indicate that it may be possible to get a fairly high degree of utilisation of natural uranium by making use of the plutonium produced.

Types of Reactor

The basic component of a reactor is the fuel element with its coolant channel and surrounding moderator. For a given design, with fixed enrichment of the fuel, there is a minimum size called the critical size of reactor core to achieve a chain reaction. The size of the core of a power reactor must be somewhat larger than this critical size to obtain sufficient reactivity to take care of fuel depletion and poisoning. The tonnage of uranium in the core represents a capital investment in fuel. The interest on the fuel investment per shaft horsepower-hour will vary with the heat rating and the utilisation of the reactor. Another factor of importance is the total heat produced or burn-up before the fuel elements are withdrawn from the reactor. From the marine point of view the overall diameter of a reactor is also important as on this will depend to a large extent the weight of biological shielding.

Gas-Cooled Graphite-Moderated Reactor.—This reactor, using natural uranium as a fuel, is being developed in this country for land power generation. The moderator of the Calder Hall reactor consists of a large number of graphite blocks built in the form of a solid cylinder having a diameter of 36ft and a height of 27ft and weighing over 1000 tons. It contains a large number of vertical channels in which are stacked rods of uranium metal canned in a magnesium alloy. The heat generated in the 130 tons of uranium rods is removed by carbon dioxide gas at 100 lb per square inch, which flows up through the channels over the surface of the rods and passes at a temperature of 350 deg. Cent. to the heat exchangers. The gas leaves the lower end of the heat exchangers to pass through the blowers, which recirculate it to the lower end of the core. A dual pressure steam system is used and each heat exchanger is made up of banks of stud welded tubes consisting of h.p. and l.p. economiser, boiler and superheater sections.

The core is contained in a steel pressure vessel about 40ft in diameter and 60ft in height, fabricated from steel plates 2in in thickness. The reactor vessel is surrounded by a thermal shield of 6in mild steel plates to absorb the thermal neutrons escaping from the core, and outside this is a concrete biological shield. The space between the thermal and biological shield is used for induced draught air cooling.

The use of natural uranium as a fuel requires a large reactor having a considerable investment of nuclear fuel. In current designs a heat rating of about 2MW per ton is achieved and leads to a fuel investment charge of about 0·05d. per shaft horsepower-hour, but with the expected burn-up of 3000MW of heat per ton, the direct fuel cost is likely to be of the order of 0·2d. per shaft horsepower-hour. For power outputs of less than about 60,000 s.h.p. the capital cost of the reactor per shaft horsepower may well be so large that it is not attractive commercially.

Gas-Cooled Heavy-Water Reactor.—A reactor of this type has not yet been built but a design has recently been proposed in the U.S.S.R. The general arrangement is shown in Fig. 1 and the

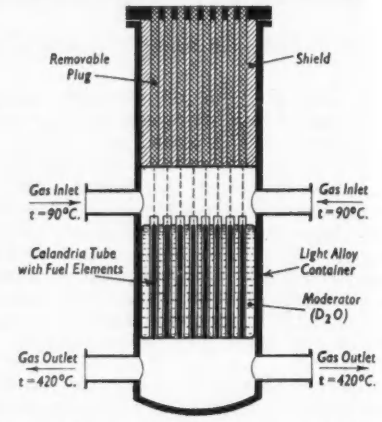


Fig. 1—Diagram of the gas-cooled heavy-water reactor

form of the fuel channel is illustrated in Fig. 2. Within the reactor pressure vessel is a light alloy tank pierced through with calandria tubes. The tank is filled with heavy water and the fuel elements are suspended in the calandria tubes from removable plugs in the upper shield. The fuel elements consist of rods or plates of natural uranium clad in a light metal which withstands a maximum temperature of 550 deg. Cent. and are enclosed in a light alloy baffle tube. The narrow annular gap between the baffle tube and calandria tube forms a passage for gas cooling of the tubes. The temperature of the calandria tube is kept low and the coolant and the heavy water are kept at

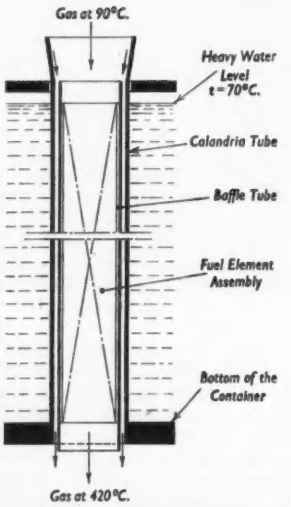


Fig. 2—A calandria tube

the same pressure so that there are virtually no pressure stresses in this tube. Carbon dioxide is used as a coolant at a pressure between 590 and 880 lb per square inch.

Heavy water is an excellent moderator and a fuel investment as small as 15 tons of natural uranium may be practicable with a pressure vessel diameter of perhaps 15ft. The moderator/uranium volume ratio is of the order of 15 to 25, compared with over 45 for graphite; conse-

quently the core size is smaller for the same fuel investment. The smaller size permits higher gas pressures, giving higher heat ratings and smaller heat exchangers. The weights of reactor and shielding for 20,000 s.h.p. output may not be much in excess of 2000 tons. Heavy water is not at present produced in this country but recent estimates of production costs are not prohibitive and the recently quoted United States price is £20,000 per ton.

Pressurised Water Reactor.—Hydrogen is very effective in slowing down neutrons and the use of water as a moderator leads to small reactor cores with moderator/uranium volume ratios of 2 or 3. The hydrogen does, however, absorb an appreciable number of neutrons and enriched fuel is essential for this type of reactor. The moderator and coolant water must be pressurised to prevent boiling in the core. The oxygen in the water becomes radioactive and emits gamma-rays, and shielding of the primary circuits is necessary, but this activity is very short-lived and is not troublesome from the point of view of maintenance.

Although development of the pressurised water reactor was initiated for submarine propulsion this reactor is now being applied in the United States to other classes of naval vessels and to America's first nuclear-powered merchant ship.

In an American design of pressurised water reactor for a power station, the reactor produces 480MW of heat from a core 74in in diameter by 100in in height, the primary water pressure is 2000 lb per square inch and the reactor vessel 109in in internal diameter by 8in in thickness. The coolant inlet and outlet temperatures are 487 deg. and 529 deg. Fah., respectively, and dry saturated steam at 521 lb per square inch is generated. The enrichment of the fuel is 2·6 per cent U-235 and about 15MW of heat are produced per ton of fuel in the core. It is anticipated that a burn-up of 8000MW days of heat per ton will be achieved before reprocessing is necessary.

The diagrammatic layout of the reactor and steam system is shown in Fig. 3.

In the design of a pressurised water reactor system is incorporated in the design and facilities for organic liquid purification and make-up. The proposed steam conditions are 415 lb per square inch gauge, 520 deg. Fah.

Organic liquids have certain potential advantages over water as a coolant ; they include low vapour pressure, low chemical activity and low induced activity. The low vapour pressure permits a much lower pressure in the primary

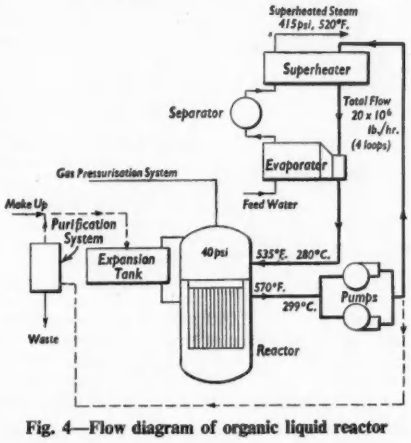


Fig. 4—Flow diagram of organic liquid reactor

circuit and this may be in the range 40 to 150 lb per square inch ; it also eases the problem of containment. The absence of significant induced activity should make shielding of the primary circuit unnecessary and might well obviate the need for complete leak tightness of the primary circuit.

Against these advantages have to be set certain disadvantages. The proposed liquids have low thermal conductivity and specific heat, and it may be difficult to achieve a sufficiently high heat rating for the fuel investment charges not to be excessive. They break down under irradiation, and the rate of breakdown increases rapidly

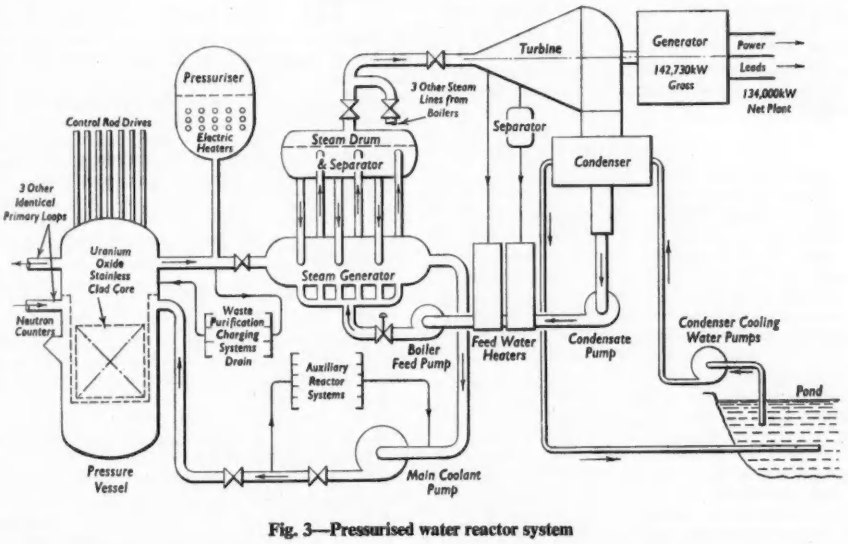


Fig. 3—Pressurised water reactor system

problems arise from the high system pressure, the corrosive action of the water under irradiation, the activity of the primary circuit, and the poor steam conditions.

Organic Liquid Moderated and Cooled Reactor.—Liquids such as the polyphenyls have sufficiently good stability under temperature and irradiation to be considered as reactor coolants, and from the point of view of core size, enrichment of fuel and direct fuel cost, an organic liquid reactor may be expected to be very similar to a pressurised water reactor. A reactor experiment to test an organic liquid as a moderator and reactor coolant is being built in the United States.

A schematic flow diagram is shown in Fig. 4, from which it will be seen that a gas pressurising

above about 400 deg. Cent., and means of moving the products of polymerisation would have to be provided, while there might be fire and toxicity hazards. The most promising liquids from the point of view of stability are not liquid at room temperature and trace heating of the primary circuit is necessary.

A reactor producing 20,000 s.h.p. might have a pressure vessel diameter of 6ft to 7ft and a shielding weight not much in excess of 500 tons. The capital cost of such a system may well be sufficiently low for smaller power outputs to be economic.

Other Types of Reactor.—Several other types of reactor have been proposed for ship propulsion, but all of these are enriched systems. In the United States the Atomic Energy Commission and the Maritime Administration have announced a joint long-range programme for developing reactor systems for commercially competitive propulsive power for merchant ships, in addition to the work now in progress on the first nuclear-powered merchant ship. The reactor systems are as follows :

Study	Company
Organic-moderated and cooled reactor	North American Aviation Inc.
Closed-cycle gas turbine with gas-cooled reactor	Ford Instrument Company
Closed-cycle gas turbine with hydride-moderated, helium-cooled reactor	General Dynamics Corpn.
Boiling water reactor	A.M.F. Atomics Inc.
Closed-cycle gas turbine graphite-moderated, helium-cooled reactor	General Motors Corpn.
Advanced type pressurised water reactor	Babcock and Wilcox Company.

It would appear that the fairly low cost of enriched fuel in the United States will make it possible to consider systems requiring appreciable enrichment.

Prospects for the Commercial Application of Nuclear Power to Ship Propulsion

In this country the commercial application of nuclear power to the propulsion of ships will not be possible for some years to come unless natural-uranium-fuelled reactors are found to be attractive for this purpose, or unless enriched fuel is available at a reasonable price. The main advantage to be gained by the use of nuclear power is the promise of low direct fuel costs and the question arises whether lower fuel costs would lead to higher speeds and increases in earning capacity and whether the saving in the annual fuel bill, if an increase in speed is not justified, is likely to make worth while the additional capital investment for the reactor.

Very few ships have powers higher than 20,000 s.h.p., which may be the minimum for which large natural uranium reactors are attractive, but the trend towards larger oil tankers for the transport of crude oil is increasing the number of vessels in this category. Therefore, increasing interest has been taken in the possible use of nuclear power for the propulsion of the large oil tankers which might be used in the future to transport crude oil to this country from the Middle East by the Cape route. The power and speed of typical large tankers is given in Table I and it is evident that the possible

Table I

Owner	Dead-weight, tons	S.h.p.	Speed, knots	Remarks
British Tanker Company	32,000	12,500	15	Single screw. A large number of 28,000-ton tankers have been built since 1950.
Niarchos	47,750	18,000	17	Delivered 1956. The largest tanker built in United Kingdom. Single screw.
Tidewater Assoc. Oil Company	65,789	22,000	17	Building in France. Single screw.
National Bulk Carriers	85,515	19,500	14½	Built in Japan. Delivered 1956. Single screw.
Niarchos	106,500	43,000	18	Twin screw. Ordered in United States.
(Current trend)	47,000	16,000	15½	Single screw.

application of natural uranium reactors is likely to be limited to tankers of about 45,000 tons deadweight and above. In January, 1957, there were twenty-one vessels over 40,000 tons deadweight in service or launched and 190 building or contracted.

A feasibility study has been carried out by B.S.R.A., with the co-operation of tanker owners, of the application of nuclear power to large tankers and it is of interest to refer to the results for single-screw tankers of 47,000 tons deadweight. There is a possibility that a gas-cooled heavy-water-moderated natural-uranium reactor might be attractive for the propulsion of these vessels. When enriched fuel becomes available graphite or hydrogen-moderated reactors can also be considered.

Application of Nuclear Propulsion to 47,000 tons d.w. Oil Tankers

The method adopted in this study is to calculate the cost of transport per ton of oil delivered

from the Middle East to the United Kingdom in a conventional tanker and make similar calculations for equivalent nuclear-powered vessels in which the deadweight is reduced due to the additional machinery and associated structural weight. For these nuclear vessels the cost of transporting oil has been calculated for : (*a*) a range of nuclear fuel costs, including fuel investment charge, and (*b*) a range of figures by which the machinery and associated structural weight might be regarded as additional to that of the conventional vessel. The saving in cost of transporting oil in a nuclear tanker as compared with the cost for a conventional vessel is capitalised in each instance. From this saving is calculated the additional capital expenditure which could be incurred on the reactor and associated steam-raising equipment of the nuclear vessel for it to be commercially competitive with the conventional ship.

The conventional vessel taken for the basis of this study is representative of current trends in this country and is a 15¾-knot, 16,000 s.h.p., 47,000-ton tanker. It was decided to determine the permissible reactor cost of a 47,000-ton nuclear-powered vessel with 16,000 s.h.p. and also for a vessel of the same deadweight with 22,000 s.h.p. Consideration of the adjustment of

TABLE II—*Estimated Speed and Appropriate Dimensions of 47,000-ton Tanker with Increased Power*

S.h.p. available	16,000	22,000
Appropriate dimensions :		
Length, ft	710	743
Breadth, ft	102·5	103·5
Draught, ft	38	38
Block coefficient	0·785	0·754
Displacement, tons	62,300	62,950
Propeller diameter, ft	22·5	24·0
Service r.p.m.	106	106
R.p.m. for onset of cavitation	115	107
Service speed, knots	15¾	17
Quasi-propulsive coefficient	0·646	0·649

the proportions and fineness of the 47,000-tonner and an estimation of the approximate service speed to suit the increase in power from 16,000 to 22,000 s.h.p. was a necessary preliminary to the economic appraisal and the results are given in Table II.

For the conventional vessel, November, 1956, prices of bunkers are taken, and for the nuclear-powered vessels fuel costs, including investment charge, of 0·2d., 0·3d. and 0·4d. per shaft horsepower-hour " all purposes " were assumed. The increase in the machinery and associated structural weight of the nuclear-powered vessels above that of the conventional vessel was taken at 500 tons, 1500 tons, 2500 tons and 3500 tons in each case.

One of the routes considered for the comparison was from the Middle East to the United Kingdom via the Cape in both directions. The yearly average deadweight was taken for the conventional ship and it was found that the cargo carried in the nuclear and conventional ships was the same when the additional machinery weight of the nuclear-powered vessel was 1700 tons. For an additional machinery weight greater than this figure the nuclear ship carried less cargo and for a smaller weight it carried more cargo than the conventional vessel.

In the economic analysis, November, 1956, prices for bunkers were taken and other running costs were based on 1957 levels. It was assumed that the latter costs would be common and that the time out of service and the time per voyage for loading and discharging cargo were also the same. For the purposes of calculating the capital charges, the cost of the conventional ship was taken at January, 1957, figures (£3,000,000). The capital charges assumed for this investigation are made up of depreciation over twenty years (5 per cent), 6 per cent interest on the reducing capital (3·15 per cent average) and an insurance rate of 1·25 per cent, making 9·4 per cent in all. The same rates were taken for the nuclear-powered vessels.

From the difference between the transport cost per ton delivered to the United Kingdom in the nuclear ships and the conventional vessel was calculated the capital which could be expended on the nuclear-powered vessels above that on the conventional vessel to give the same transport cost per ton of oil delivered. From these capital sums a first approximation to the permissible cost of the reactor and steam-raising equipment was obtained by adding the cost of the conventional boilers. For the higher-powered nuclear vessel the additional cost of the finer hull and the additional cost of the machinery was subtracted. The results are given in Table III. An increase or decrease in the nuclear fuel cost of 0·1d. per shaft horsepower-hour results in a decrease or increase in the permissible reactor cost of £530,000 for the 16,000 s.h.p. ship, and

TABLE III—*Permissible Reactor Cost : 47,000-ton deadweight Nuclear-Powered Tankers*

Nuclear fuel cost 0·2d. per shaft horsepower-hour.
Voyage : Mina/U.K./Mina via the Cape.

Vessel	Cost	Additional machinery, weight, tons			
		500	1,500	2,500	3,500
16,000 s.h.p....	Permissible cost, million pounds	1·45	1·29	1·13	0·98
15¾ knots ...	Permissible cost/ s.h.p., pounds	91	81	71	61
22,000 s.h.p....	Permissible cost, million pounds	1·28	1·11	0·94	0·78
17 knots ...	Permissible cost/ s.h.p., pounds	58	51	43	53

£720,000 for the 22,000 s.h.p. ship. It follows that the nuclear fuel cost would have to be much less than 0·2d. per shaft horsepower-hour, before increased speed of operation would lead to an increase in permissible reactor cost, on this basis of analysis.

An increase in the price of bunkers of 0·1d. per shaft horsepower-hour (about 33s. per ton) results in an increase in the permissible reactor cost of about £540,000 to £500,000, reducing with increasing machinery weight, for the 16,000 s.h.p. vessel and £580,000 to £540,000 for the 22,000 s.h.p. vessel. If the depreciation is taken over sixteen years instead of twenty years with the same rate of interest, the permissible reactor cost is decreased by about £8 to £11 per shaft horsepower and if the depreciation is taken over twenty-four years the permissible reactor cost is increased by roughly the same amount. It may be concluded that provided the direct fuel cost of nuclear power is low, the additional investment which can be justified on the basis of this analysis is appreciable. For larger vessels than those considered nuclear power is undoubtedly more attractive, but the field of application is smaller. For very large tankers the possibility that a graphite-moderated, natural uranium reactor might be economically attractive cannot be ruled out.

Some Practical Considerations

Fuel Elements.—In natural-uranium-fuelled reactors the uranium is in metallic form, and although there is as yet little experience of the performance of such fuel elements when subjected to the extended burn-up necessary to achieve a low fuel cost, there is every indication that the incidence of failures would be such that provision would have to be made for the replacement of faulty fuel elements at sea. Least complication would be introduced if this operation were carried out with the reactors shut down, and the ship could proceed at part speed using steam from an auxiliary boiler. If the incidence of failure were high much time would be lost on voyage if this procedure were adopted and provision would have to be made to change fuel elements when under load, but this facility would be expensive and probably difficult to arrange.

When the more expensive enriched uranium is used it may be possible to develop fuel elements which are sufficiently robust that provision for changing fuel elements at sea would not be necessary, and that failures would be so rare that they could be considered as a major breakdown. If a coolant is used which does not react with the uranium or the uranium is dispersed in a material which does not react with the coolant, the build-up of activity in the primary circuit following a failure of a fuel element may be so slow that the voyage can be completed before it is necessary to change the faulty element on this account.

Control.—Only a very small amount of excess reactivity can be built into natural uranium reactors and if high heat ratings are achieved, there may be some difficulty in starting up immediately after shut-down due to transient xenon poisoning. The heat capacity of natural uranium reactors is large and also it is doubtful whether thermal cycling of the uranium metal fuel elements could be permitted. Consequently, it is likely that a dump condenser to take the full-power steam output would be installed and this could be used for manœuvring, and to overcome difficulties from transient xenon poisoning. With enriched systems the fuel elements may be made sufficiently robust and manœuvring by varying the power of the reactor may be possible. A reactor system is well suited for automatic control and it could be that a smaller number of watch-keepers would be required than for oil-fired boilers. The authors wish to dispel the popular belief that a crew of highly qualified scientists will be required.

Biological Shielding.—The conclusion was drawn from the study of the application of nuclear power to 47,000-ton tankers that each ton of shielding reduced the permissible cost of the reactor by about £160. Consequently, there is much to be gained from reducing the weight of shielding below that of the usual 8ft of concrete. Reduction in shielding weight may extend the field of application of natural uranium reactors to smaller vessels. For some applications such as oil tankers, some use may be made of the cargo for part shielding, but use of this expedient might be limited by operational considerations and the requirement that the hull structure should not be permitted to become active and make repairs and maintenance difficult.

Machinery Arrangement.—It seems probable that in a nuclear-powered tanker the reactor would be installed just forward of the steam turbine and it might be necessary to encroach on the cargo space. With the large natural uranium reactors there may be some difficulties regarding trim and hull strength and the reactor might have to be sited somewhat further forward. There would almost certainly be some structural problem in providing a rigid seating for the reactor and yet allowing for the flexing of the hull in a seaway, while access would have to be provided to the reactor through the upper deck. Additional turbo-generators would be required to provide power for the coolant circulating pumps or blowers and probably the diesel generator capacity would also have to be increased.

Installation.—The weight of the pressure vessel of a natural uranium reactor might be in excess of the maximum lift of the normal fitting-out crane and a reactor would probably have to be built into the hull as part of the ship structure ; this arrangement has disadvantages. Attention will have to be given to the problem of maintenance, and in the case of a graphite-moderated reactor renewal of the pressure vessel would be a major operation. With a heavy-water-moderated reactor this operation would be easier as the heavy water could be discharged to a dump tank.

Safety

There are many technical features which contribute to the safety of a reactor such as low excess reactivity, large heat capacity and large negative temperature coefficient of reactivity, but unless a system is completely self-stabilising reliance has to be placed on the control and shut-off rods. Considerable development will be required to produce control and shut-off rod actuating systems which are foolproof, fail-safe, and operate under all conditions at sea and are not put out of action by collision or stranding. Not only have the consequences of a pump failure and loss of coolant to be considered, but also the loss of sea water services. When the reactor is shut down heat continues to be generated from the decay of the fission products, starting at about 7 per cent of the power level before shut-down and falling quickly to about 1 per cent after twenty-four hours. Failure to provide a reliable method of removing this heat might result in melting of the fuel elements. It is advantageous if this heat can be removed by natural circulation of the coolant.

Little experience has yet been gained with the operation of power reactors and a safety philosophy has not yet been fully worked out. The pressurised water and organic liquid reactors have of necessity a large amount of excess reactivity when cold and present designs have a relatively small heat capacity. As a precautionary measure containment is provided for the vapour

which might be released following a failure of the primary circuit. With a pressurised water reactor with a primary circuit pressure of 1500 to 2000 lb per square inch this is difficult to arrange, and in a merchant ship a massive pressure vessel would be required for this purpose. The primary circuit pressure of an organic liquid reactor is much less and there should be no problem in providing containment.

Consideration must be given to the possible consequences of normal marine hazards of collision and fire. The possible spread of radioactivity following the sinking of a nuclear-powered ship in confined waters cannot be ignored. It will be necessary to carry out experimental work to determine a measure of the hazard involved and it may be necessary to specify a maximum rate of corrosion of fuel elements in salt and estuarine waters.

The low-rated natural uranium reactors now being built in this country are considered to be safe, but none the less as a safety precaution are still located away from centres of population : ships must enter ports. It will be rather more difficult to maintain the same standard for advanced designs of power stations with higher heat ratings and for marine reactors. Higher ratings may be achieved by using bundles of small-diameter rods as the fuel elements, but there seem to be advantages to be gained if a sufficiently high enrichment can be used, in dispersing the uranium to some extent in a ceramic material such as graphite, and in this way raise the maximum temperature at which the fission products are retained in the fuel rods.

Before nuclear-powered merchant ships can be brought into general use international agreements will have to be established to cover the operation of such vessels. International standards of containment, safety factors and operation will have to be agreed before the use of nuclear power for this application is widespread. The question of insurance is also an important one and the coverage necessary will have to be defined.

Conclusions

The prospects are likely to be affected by the shortage of enriched fuel in this country, but the low direct-fuel cost of power from natural uranium reactors may well lead to these being commercially attractive for the propulsion of large ships in the near future, for which powers of the order of 20,000 s.h.p. and above are appropriate. It should be noted that some three or four years would probably be required to develop a natural uranium heavy-water-moderated reactor for this purpose ; whether or not such a development takes place in this country may well depend on the prospects for enriched fuel in the early 1960s. The only power reactor which has so far been developed in this country is the gas-cooled, graphite-moderated reactor, and should there by any immediate project for a nuclear-powered merchant ship there would be no alternative to this type, probably with enriched fuel.

It must be realised that with the passage of time the cost of nuclear power will certainly come down due to technical advances in the utilisation of nuclear fuel, whereas the cost of power from coal and oil will rise. For nuclear power stations, Hinton has recently forecast that by 1990 the cost of nuclear power would be some three-eighths of that produced by coal-fired stations. It appears therefore just a question of time before nuclear propulsion will show to advantage.

British Iron and Steel Research in 1956

THE British Iron and Steel Research Association has issued its report for 1956. The work of the Association is conducted by eight main divisions dealing respectively with iron making, steelmaking, mechanical working, plant engineering, general metallurgy, chemistry, physics, and operational research. General progress is reported and we note some of the leading developments below.

Investigation of the sintering process continued. Studies in the laboratory showed that good ignition is important in eliminating sulphur from the filter bed, giving stronger sinter at the top. Inadequate ignition efficiency leads to the retention of sulphur in the upper layers of the bed, and the sinter obtained is generally weak. Pelletisation of fine ores to improve their sintering properties was studied. Disc pelletisers (" flying saucers ") were applied to fine home ores, and the product proved much more permeable on the sinter bed. Unusual ores and agglomerates (including some Russian samples) were assessed.

The importance of keeping the temperature of the slag in the blast furnace above the liquidus value led to the development of a device for the rapid and accurate measurement of slag temperature. Crystal growth in the liquid slag can be observed directly with the instrument, and a large number of slags were examined in this way. The measured liquidus temperatures turned out to be lower than the liquidus temperature of a mixture consisting entirely of lime, magnesia, alumina and silica. The viscous behaviour of slags was also investigated, and the viscosity itself related to the liquidus temperature.

Further model studies were made on the arrangement of water-cooled baffles in a blast furnace to prevent material on the walls from moving, so making part of the charge act as the furnace lining. The limitations of water-cooling have apparently been recognised in Russia and Czechoslovakia, where proposals remarkably similar to those of B.I.S.R.A. are reported to have been made.

Intensive preliminary work on the " Cyclosteel " process* was completed, and a small-scale pilot plant is to be erected on the basis of the data obtained.

Steelmaking research was mainly devoted to the increase of open-hearth furnace life and output, and to the improvement of regenerator efficiency. Emphasis was placed on the development of those open-hearth furnaces that had recently been converted to oil firing. There was also co-operation in a number of works trials on refinement with oxygen, carried out in anticipation of the tonnage supply to be available later.

The design of the B.I.S.R.A. twin-image radiation pyrometer for use on open-hearth furnace flames was improved, and prototypes were under construction for trials in the field. Punched-tape equipment was built for recording and analysing data, and this was expected to increase the speed of investigations. New cermets for immersion-thermocouple sheaths were examined ; molybdenum alumina gave promising results.

Research on continuous casting problems was intensified, and it was decided to erect a second experimental plant. Experience on the original test plant had led to improvements that enabled a single operator to regulate flow into the mould, lubrication, and the starting and stopping of a cast. Member firms co-operated in metallurgical examinations of continuously cast material ; these showed little variation in axial soundness as between ingots cast at 36in per minute and ingots cast at 72in per minute. Member firms also assisted in tests on feeder heads. Difficulties were found in experiments on the immersion casting of steel. The method of passing the strip upwards through a refractory slot into liquid steel appeared to be impracticable.

The B.I.S.R.A. screw-down method of automatic thickness control on rolling mills having been adopted commercially, research emphasis moved from single-stand to continuous multi-stand applications of it. A miniature three-stand mill was built to investigate theories that had been evolved. Electrical and mechanical characteristics of each stand, and the distance between stands, can be varied for experimental purposes. A hydraulic method was devised for modulating roll force, and preliminary tests on an experimental mill were successful using manual control : fully automatic operation was the actual objective of the work.

Development continued on three schemes for position control of the rolls in primary mills. In each of them the operator is free to change the rolling programme at any time.

Position control was also tried on the Association's 200-ton forging press, with promising results, and considerable interest in the industry is reported.

A form of small, replaceable " packaged " controller was developed for complex electrical drives. This device, known as a " translator," transmits instructions to the drive in accordance with simple input settings. Advantages are that the circuit designer can arrange a contactor sequence as easily as he can specify his requirements, and the operator's controls can be more logically connected with the process. Substantial savings are expected in bulk and cost of control gear, together with increased flexibility and easier maintenance.

A survey of steel works operations from an ergonomic standpoint showed that there was much scope for improvement, and advice was given to many member firms. New controller and control point layouts were developed, and more work was done on the design of hand and foot controls. Works trials showed that three notches were sufficient for hand controllers on cranes, not six as installed.

New coatings and their possible applications were investigated. Strip coated with lead-tin alloy was found to be useful in the manufacture of motor-car radiators. This strip was prepared on an experimental line in which the coating was applied by rollers. Preliminary experiments showed that an iron-tin coating alloy with about 30 per cent tin resists alkaline liquid detergents which had previously to be packed in lacquered or chemically treated containers. X-ray fluorescence equipment for measuring the thickness of tin coatings on steel was developed in a form suitable for use in tinplate works. Coating and drawing processes were combined in a method for the production of tinned copper wire. Experiments in the cold reduction of aluminised steel showed great improvement of surface lustre. A continuous lacquering machine was built, and a satisfactory process evolved for preparing a P.V.C.-steel laminate which is attractive, hard wearing, easily deep-drawn, and is believed to be superior to its American counterpart.

Preliminary studies on 1in bars of commercial semi-killed structural steel indicated that thermal history and subsequent heat treatment may be more critical than was previously thought, possibly because of the influence of certain minor elements.

Experiments suggested that the first additions of nitrogen to commercial iron electrical sheet combined with another impurity, and were precipitated in a relatively harmless form. With further addition of nitrogen the hysteresis increased in the same way as for highly pure silicon iron.

High-temperature creep tests were conducted on bolt steels and turbine casing materials. Search for a ferritic steel with high resistance to scaling led to the discovery of a chrome-molybdenum-titanium steel with creep properties rather better than those of existing chrome-molybdenum and chrome-molybdenum-vanadium steels of lower chrome content.

A simple method was devised for the measurement of the average dust content of a gas in about ten minutes. Research on the cleaning of gases continued in collaboration with the British Iron and Steel Federation.

The membership of the Association increased to 418 in 1956. The main sources of income continued to be a grant of £450,000 per annum from the British Iron and Steel Federation and £100,000 from the Department of Scientific and Industrial Research. These, with membership fees and other receipts, gave a total income of £614,404.

* The Engineer, September 7, 1956.

LETTERS AND LITERATURE

Letters to the Editor

(We do not hold ourselves responsible for the opinions of our correspondents)

THAMES BARRAGE

SIR,—In your edition for June 14, 1957, I have read your leading article "The Thames Estuary Investigations" with great appreciation, and having regard to the knowledge which has been collected about the estuary I hope you will not mind a comment that the Thames barrage scheme would not provide the unqualified benefits which the last paragraph of your article might lead your readers to suppose. There is no doubt that if a barrage were situated on one of the sites which have been proposed, it would change the appearance of the Thames through London and the character of the navigation upon it, but it might well be argued that the uniform level of the water would lack a great deal of the charm which the tidal changes now provide and that navigation without tidal assistance would be more expensive, so that both these matters are debatable. It is also suggested that a barrage might assist in recharging the chalk with fresh water. It must, however, be appreciated that the rise in the water table in the low lying areas north and south of the river which would inevitably follow the construction of a barrage would result in dampness, if not flooding, of many basements and the underground railway system with consequential difficulties and probably hardship to owners large and small.

The insuperable problem, however, with the barrage is providing sufficient locks to accommodate the shipping which must pass through it to maintain the river commerce. Assuming that the cost of providing locks can be met, and a little thought will show that it is difficult to say what authorities would benefit sufficiently to wish to put up the many millions of pounds which would be needed to construct these locks, vessels would necessarily arrive below the barrier with the tide, and the congestion might well rival that in the Pool of London before the docks were built. At the present time ships moving up the river may pass through any of the ten entrance locks to the various groups of docks, or stop at the wharves, jetties or warehouses lining the banks of the river. Even if it were possible to build ten locks in the barrage, marshalling the ships through would create an insoluble navigational problem and the congestion of ships could not be relieved. Vessels proceeding down river on the artificial lake could of course be controlled, but it would still be necessary to pass them through the locks in the barrage when the tide on the lower side was suitable for them to proceed on their journey to the sea.

So far as I am aware the barrage scheme has always been a controversial project, but on the other hand the barrier for preventing flooding due to storm surges is a possible solution to a real and urgent problem. It could provide a means of protecting the lives and property of a great many people from a catastrophic event which was avoided only by a few inches in January, 1953. After studying the decision of the government of the Netherlands to defend that country by an entirely new and greater dyke because the old dykes could not be effectively raised, it is not difficult to foresee the grave hardship and heavy cost which would follow if it were found necessary to raise the banks of the Thames several feet, and yet something of this order of added protection would seem to be the only alternative to a surge barrier and it is to be hoped that the consulting engineers to whom the investigation has been entrusted will soon be able to present their advice to those responsible for taking a decision.

G. A. WILSON
Chief Engineer

Port of London Authority,
London, E.C.3.
July 5, 1957.

TVA COSTS AND PRICES

SIR,—Our attention has been drawn to a letter in your May 10 issue from Mr. George L. Schlaepfer, of Detroit, Michigan, in which he contends that low electric rates in the TVA area are simply a matter of low taxes and interest. For several reasons his arguments and conclusions are not valid.

The table of figures which accompanied his letter contributes no light on the question. It attempts to compare the operations of the Detroit Edison Company, which distributes electricity retail to its customers, with the TVA power operations which are wholesale only. It ignores the fact that of the 53·8 billion kWh sales of TVA in 1956 nearly three-fifths—more than 57 per cent—was used by the Government itself, through the Atomic Energy Commission and other Federal agencies; revenues from such sales are specifically, and properly, excluded by the TVA Act from the base on which payments in lieu of state and local taxes are determined. The table does not include the 6,910,000 dollars in taxes and tax equivalents paid by the co-operative and municipal systems which distribute TVA power, which would bring the total of state and local tax payments to more than 11,000,000 dollars. Finally, Mr. Schlaepfer, somewhere along the line, simply dropped out the TVA's power net operating revenues of 53,900,000 dollars for 1956 from which interest, income taxes, and dividends would be paid if they were required. The net operating revenues represented a return of 3·9 per cent on the average net power investment, which is sufficient to cover the cost of money to the Government and still leave a substantial margin of earnings. Over the entire twenty-three-year period of the Authority's operations, the return has averaged 4 per cent annually.

It is virtually impossible to establish a direct connection between taxes and the levels of electric rates, as Mr. Schlaepfer might have discovered had he made comparisons between private companies. In Detroit, according to the latest report of the Federal Power Commission, Mr. Schlaepfer must pay 7·74 dollars for 250kWh per month. In Knoxville, Tennessee, he would pay 5·00 dollars for the same amount of TVA power. He could do even better in Spokane, Washington, or Madison, Wisconsin, both served by private companies, where his bill would be 4·66 dollars or 4·85 dollars respectively, or in a number of cities where the cost would be less than 6·00 dollars. On the other hand, he could do worse in other large cities where the cost for 250kWh per month is between 9 dollars and 10 dollars, or in smaller communities where the bill would range up to 12 dollars. Obviously, since these are rates charged by private companies, differences in taxes and interest do not explain the wide divergences.

Like most critics of TVA rates, Mr. Schlaepfer avoids discussion of the major reason why they are low, namely, the policy of deliberately pricing electricity low in order to encourage greater use. In brief, abundant sales of electricity at low rates, rather than limited sales at high rates, were depended upon to bring in the revenues necessary to cover the costs of service. As a result, taking residential service as an example, the average household in the TVA area uses nearly 6000kWh a year, about double the average use per customer in the nation.

PAUL L. EVANS,
Director of Information,
Tennessee Valley Authority

Knoxville,
Tennessee,
June 19, 1957.

ARRIS AND ARRIDGE

SIR,—Some time ago I became interested in the word "arris," and its otner form "arridge," much used in the North of England. The dictionaries give this as meaning (C O.D., for example) "a sharp edge formed by angular contact of two plane or curved surfaces." On the other hand, I have been told that engineers use it in a different sense, of the circle of waste material pushed out by a drill; but, if this is so, it is a word more often spoken than written, and I have not been able to find any examples of its printed use. Could any of your readers help me to such an example (for instance in a handbook or text book), which will illustrate this second meaning—or else prove to me that my quite authoritative informer was wrong?

W. H. STEVENSON

Kumasi, Ghana,
June, 27, 1957.

Book Reviews

Engineering Mathematics. By KENNETH S. MILLER. Constable and Co., Ltd., 10, Orange Street, London, W.C.2. Price 47s. 6d.

"MATHEMATICS" is a word of wide application and range. Although there is a more precisely acknowledged meaning to the term "engineer," there is a tendency to use the word "engineering" to embrace a diverse field of subjects. Consequently it is not possible to deduce from the title "*Engineering Mathematics*" the aim or standard of the book. The author is Associate Professor of Mathematics at New York University. He gives his objective as "strengthening the mathematical background of engineering students in the first year of graduate work." This is, therefore, a book on more advanced mathematics, and it presupposes a high starting standard.

A good example of the general scope and aim of the book as a whole is given in the introduction to chapter three, "Linear Differential Equations." The author presumes that the reader has some acquaintance with the elements of ordinary differential equations and gives as one of his objectives that of "presenting some of the more advanced techniques associated with them." The chapter gives a full discussion on the fundamental theory of the general linear differential equation and then its solution by series, in particular by the method of Frobenius. The special differential equations of Legendre, Hermite and Bessel are then considered. The two preceding chapters provide results and methods necessary for this and subsequent chapters. The first deals with determinants and matrices. The use of the Kronecker delta at an early stage affords an example of the technique of employing general mathematical methods which is followed throughout the book. The second chapter on integrals is not concerned with straightforward integration, but discusses some of the important non-elementary functions which are defined by integrals. Among those considered are the Gamma function, the Beta function, the error function and elliptic integrals. Special results required subsequently for the solution of problems, such as Stirling's approximation to the factorial and Euler's constants, are also considered. The author makes the point that these results are not presented "merely as mathematical sidelights."

Two important topics, "Fourier Series and Integrals," and "Laplace Transform" form the subject matter of the next two chapters, where they are considered as extensions to the theory of differential equations. Full treatments are given. By the sixth chapter the necessary mathematical methods and results have been covered to allow for a comprehensive treatment of Network Theory. Kirchoff's laws are formulated in matrix notation: the general network equations are deduced in both the loop and node basis with steady state and transient response fully considered. The final chapter starts with a discussion on probability theory leading to the concept of a random variable with both discrete and continuous distributions. All the more important probability distributions are dealt with in turn. There is finally consideration of "stochastic" and "ergodic" processes with some applications to practical problems. There are three appendices on topics where the mathematical rigour is more advanced than in the main text: Borel Sets, Riemann-Stieltjes Integrals, Fourier Series and Integrals.

Although this is a book of advanced mathematics necessitating theorems, axioms, and a great deal of symbolic analysis, Professor Miller has adopted an easy and conversational style in his descriptive and explanatory passages. "Having completed the somewhat laborious task of finding $y_1(x)$ and $y_2(x)$, let us survey the situation and see what we have accomplished," is an example taken at random. Yet another assistance to the reader is the clear presentation of the book as a whole, with its good diagrams, well set out equations and the layout adopted.

Each chapter is subdivided into numbered sections on specific subjects which facilitates cross referencing. At the end of most sections there are exercises; references to other books and articles are listed at the end of each chapter; the answers to the exercises are collected at the end of the book. The exercises serve to illustrate the mathematics and to bring out further results. Only in a few cases are they specifically applied to practical engineering problems. The subject matter covered, the examples in the text and exercises, and the list of references, lead to the conclusion that the book was written primarily with the needs of the communication engineer in mind. References are made to Guillemin's "Communication Networks" and to Shannon's "A Mathematical Theory of Communications." In the chapter on the Fourier Transform there is a statement and proof of the important "Sampling Theorem" of information theory. The last chapter in particular introduces terms, such as "Markoff process," and discusses other processes which will be unfamiliar to the engineer who is not concerned with the mathematics of communication theory. The value of the book to the communication engineer would have been enhanced if other topics had been included. Vector analysis, the complex variable and contour integration, are examples. Despite these omissions, the book includes much material not to be found in the average book of comparable scope. *Engineering Mathematics*, in fact, goes more deeply into, and makes more use of, the methods of pure mathematics, without becoming entramelled with rigorous analysis, than the average text book on "higher" or "advanced" mathematics for engineers. As such it will be welcomed by the engineer with mathematical accomplishments, and it is highly recommended for the communication engineer who is concerned with the fundamental theory of his subject. The author and the publishers are to be commended on having produced such a valuable book for so reasonable a price as 47s. 6d.

The Physics of Electrical Contacts. By F. LLEWELLYN JONES. Oxford University Press, Amen House, Warwick Square, London, E.C.4. Price 35s.

THIS well compiled and very readable book gives a thorough discussion of the action of electrical contacts used to make and break circuits. The emphasis is on the fundamental physics of the process rather than on the design of practical switches and the book is all the more valuable for this reason. The results of investigations, both experimental and theoretical, made by a large number of workers, are included. (The Bibliography contains 111 items.) Of the investigations an important part has been carried out by the author himself and his associates at Swansea.

Electrical contacts are classified under three headings: contacts in which an arc discharge occurs, producing "arc transfer" of material between the electrodes; contacts where the voltage is too low to cause arcing but where erosion takes place by the process of "fine transfer"; very light contacts in which the main difficulty can be attributed to the resistance of surface films.

Of the nine chapters of the book six are devoted to the phenomenon of fine transfer, which is of particular interest for the contacts in telecommunication circuits, but is also a factor in initiating arc discharges in heavy switches. Considering the difficulties encountered the precision of the theoretical and experimental results is truly amazing. It is shown that as the electrodes separate, a bridge of molten metal is formed between the two surfaces at the very small region where they had been in contact. Theory and experiment agree in defining a hemispherical dividing surface between solid and liquid metal, the diameter of which is of the order of 0·003cm. Much attention is given to the determination of the amount of material transferred each time the molten bridge breaks. Many ingenious experiments are described including a recent method using radio-active isotopes devised by the author.

The theoretical work includes many mathematical derivations, some of which are of an advanced character, but the explanations are so clearly worded that the argument is always easy to follow even if the mathematics is not understood. There is a good deal of judicious repetition which is a great help, although there are times when a few more cross references to earlier pages would be useful to refresh the reader's memory. The theory of the Thomson shift, according to which the hottest point of the molten bridge is displaced due to the thermo-electric effect, is discussed at considerable length. Professor Jones concludes on the basis of his own experiments that this theory does not explain the mechanism of fine transfer and that the most important factor is probably the electric field set up between the contacts.

There is a very interesting chapter on the "Properties of Metals at High Temperatures." The application of the theories depends on a knowledge of the electrical and thermal conductivities, the Thomson coefficient and other quantities at very high temperatures. For platinum the values are required up to 4500 deg. Cent., the boiling point. Much of the available information is uncertain and incomplete, but it has been possible, by working backwards, to use the observations made on contact bridges to obtain valuable data about these properties. Chapter VIII on "Discharge Phenomena at Contacts" gives a very thorough discussion, but it is more general and less precise than that described above. A good deal of it is based on the author's own work and it contains much valuable material. The last chapter on "Surface Film Phenomena" is less satisfying. The section dealing with light duty contacts (for example, valve pins and sockets) gives a useful summary, but the brief discussion of sliding contacts is disappointing. However this is essentially a different subject and requires a book to itself. A volume which gave as thorough a treatment of carbon brush contacts as that given by Professor Jones on switch contacts would be of immense value to designers of sliprings and commutators in electrical machines.

Professor Jones is to be complimented not only on his own important contribution but also on the clear manner in which he has expounded this difficult subject.

Books Received

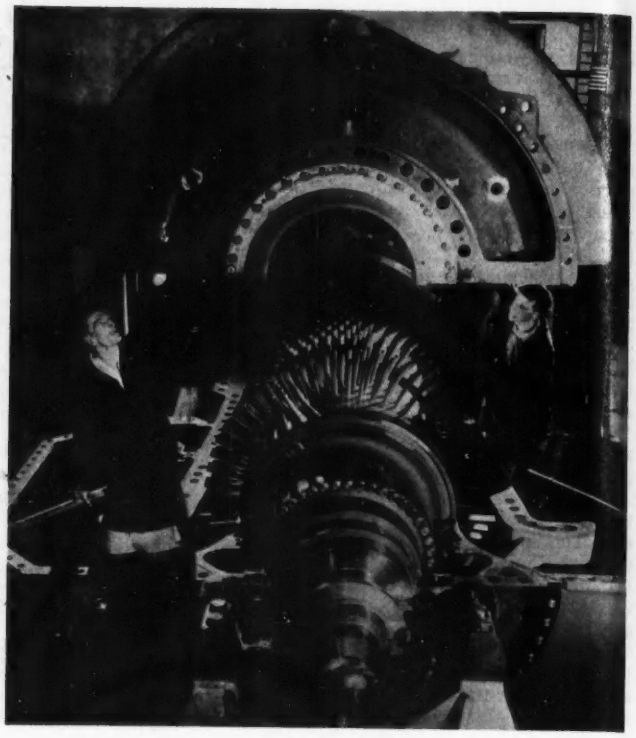
A Scientific Sampler. By Raymond Stevens, Howard F. Hamacher, and Alan A. Smith. Macmillan and Co., Ltd., St. Martin's Street, London, W.C.2. Price 45s.

Electrical Engineering: Electric Power, Telecommunications and Electronics. By D. O. Bishop. Robert Hale, Ltd., 63, Old Brompton Road, London, S.W.7. Price 8s. 6d.

Opening of the R.A.E., Bedford

No. II—(*Continued from page* 23, *July* 5)

On Thursday, June 27, *the Minister of Supply opened the Royal Aircraft Establishment, Bedford, originally known as the National Aeronautical Establishment. It comprises principally large wind tunnel facilities, and an extensive flying field having much special equipment, and being able to represent carrier landings and launches. There is a variable-frequency power station with two* 20*MW gas turbine generators, the low-pressure compressor of one of which is seen here during erection. The description of the* 8*ft by* 8*ft supersonic tunnel is continued below.*



8ft by 8ft Supersonic Tunnel

Main Compressor and Drive—The main compressor of the 8ft by 8ft supersonic tunnel is the largest of its kind in Europe. It is a ten-stage axial machine, designed to develop a pressure ratio of 2·63 : 1 with an inlet volume flow of 2,730,000 cubic feet per minute at a maximum speed of 750 r.p.m. The compressor is built in two sections—a low-pressure section fixed permanently in position and having four stages, and a removable high-pressure section of six stages : at pressure ratios below 1·47 (corresponding to a speed of 1·6 M), the l.p. section only is used.

The compressor rotors consist of built-up sub-assemblies of discs and shroud rings, a sub-assembly consisting of two blade discs separated by a shroud ring, each 12ft 3in diameter. There are two such sub-assemblies separated by an extra shroud ring for the four-stage l.p. section and three sub-assemblies with two extra shroud rings for the six-stage h.p. section.

The blade platforms span the gaps between two shrouds and are provided with T-shaped roots which enter into similar slots in the rotor discs. The circumferential gaps between the blades are filled with aluminium alloy packers which are retained by the blade platform. The locating faces of the blade platform and slot are formed as an arc of a circle of radius approximately 17½in struck from a point some 12in above the blade platform ; thus, by rotation of the blade in the plane of the compressor axis, any blade can be removed or replaced without disturbance of the remainder. The blades are prevented from moving in their slots by clamp screws fastened through the platforms to register in a circumferential groove in the disc, and bending moments are passed into the closely fitting root.

The rotors were built up at site with the rotor axis vertical and with the lower stub shaft held in a trunnion, each disc-shroud ring sub-assembly being heated and allowed to shrink on to the locating spigot. Before the through bolts were fitted an alignment check on the l.p. rotor, which over the stub shafts was 22ft 2in long and weighed 82 tons, showed that the whole assembly was within 0·001in of parallel.

After assembly, the rotor was mounted in its bearing pedestals and the journals checked for truth. A special rig had been erected for final corrective grinding of the journals, but the accuracy of assembly was such that the journal diameters ran true in their bearings to within 0·007in and only light skimming was required.

The unbladed l.p. rotor was coupled to the driving motors through its drive shaft, which is a hollow forging with a flexible disc type coupling (specially developed for this application) at each end to allow for any slight misalignment of the driving motor shaft relative to the l.p. rotor, and dynamically balanced at full speed.

The rotor blades are machined from 1 per cent chromium steel (En18) forgings ; there are fifty-three per stage ; the blade height varies from 2ft 5in at stage 1 to 2ft for stages 5 to 10 ; the chord is 11·13in and each blade weighs about 1 cwt. In an attempt to reduce the time required to carry out dynamic balancing of the bladed rotors, the rotor blades were carefully weighed and a chart compiled to show the position of every blade to give, theoretically, a dynamically balanced assembly. This study proved to be well worth while when the rotor was dynamically balanced after blading, the initial out-of-balance force as measured by vibrograph and dynectric systems being very small ; it was finally reduced to less than 480 lb expressed as a change in the load reaction at the bearing pedestals.

The procedure was repeated with the h.p. rotor, dynamic balancing, both unbladed and bladed, being carried out with the h.p. rotor connected to the l.p. rotor through the intermediate shaft coupling.

This intermediate shaft coupling is specially designed to accept up to ¼in misalignment between the l.p. and h.p. rotors and to enable them to be coupled and uncoupled quickly. In practice the actual misalignment between l.p. and h.p. rotors is said to be not greater than $^{1}/_{32}$in. Each end of the shaft carries twelve shoes which engage with splined sleeves attached to the l.p. outlet and the h.p. inlet end stub shafts. The shoes are flexibly mounted by means of rubber bushes on radial pins shrunk into the shaft. This ensures a more even distribution of the torque loading on the pins should the spline pitching be uneven, and also allows for any slight misalignment of the two rotors. The shaft is permanently engaged in the h.p. rotor and is moved to engage the l.p. rotor. A motorised oil pump acting on a piston moves the intermediate shaft by means of a spring-mounted carrier towards the l.p. rotor, while the latter is barred round at ¼ r.p.m. A single guide tooth on the intershaft brings the shoes and splines into line and ensures that the shaft engages correctly. The total movement of the intershaft is 14½in ; when it is in position a bellows type seal is made to close off the l.p. outlet and h.p. inlet bearing housing chambers and the chamber containing the intershaft from the tunnel airstream. This intermediate shaft seal is mounted on the l.p. section and is a metal-to-rubber face seal 4ft 6½in diameter, in which a steel sleeve containing the flexible metal bellows element is moved axially on guide pins under the action of closing springs until the circumferential rubber facing butts against a raised steel rim on the h.p. section intershaft casing. The seal is retracted as required by operation of a motorised oil pump acting on three radial pistons which, through cams and rollers, move the sleeve back against the action of the closing springs.

The l.p. and h.p. compressor stator casings, which form part of the tunnel pressure shell, are split in the vertical plane at flanges which are fitted with heat-tightened bolts. The half casings, each weighing 41½ tons in the case of the l.p. and 47 tons for the h.p., can be traversed outwards on special tracks for a distance of almost 9ft to facilitate inspection of the rotor and stator ; this is illustrated in Fig. 9. The l.p. stator consists of a row of inlet guide vanes followed by four stator rows ; the h.p. stator consists of six stator rows. There are fifty-two blades to each row, produced from forgings and of similar material to the rotor blades.

The main difference between stator and rotor blades lies in the method of location, which, in the case of the stator blades, consist of a cylindrical shank located in a bored hole in the casing. A keyway milled in the shank end projecting through the casing allows the stagger angle to be set accurately using a special tool. The blades are locked but could, if necessary, be adjusted over a small stagger angle. A one-seventh scale model of the compressor was built to determine the full characteristic of the machine, so it is not expected that any adjustment of stagger angle will be required : the model was displayed on the opening day.

When the compressor is working as a four-stage machine the h.p. section is replaced by a dummy section, the whole operation taking about twenty minutes to complete. The h.p. and dummy casings are each mounted on a wheeled truck, running on special guide rails laid in the main concrete foundation block which at this point is 18ft thick. The two running rails are 90ft long and have 12in wide faces.

The work of setting these heavy rail sections into the concrete was, we learn, undertaken with great care, and subsequent checking showed that they were level to within $^{1}/_{64}$in over the working length. The thrust rail, by which the

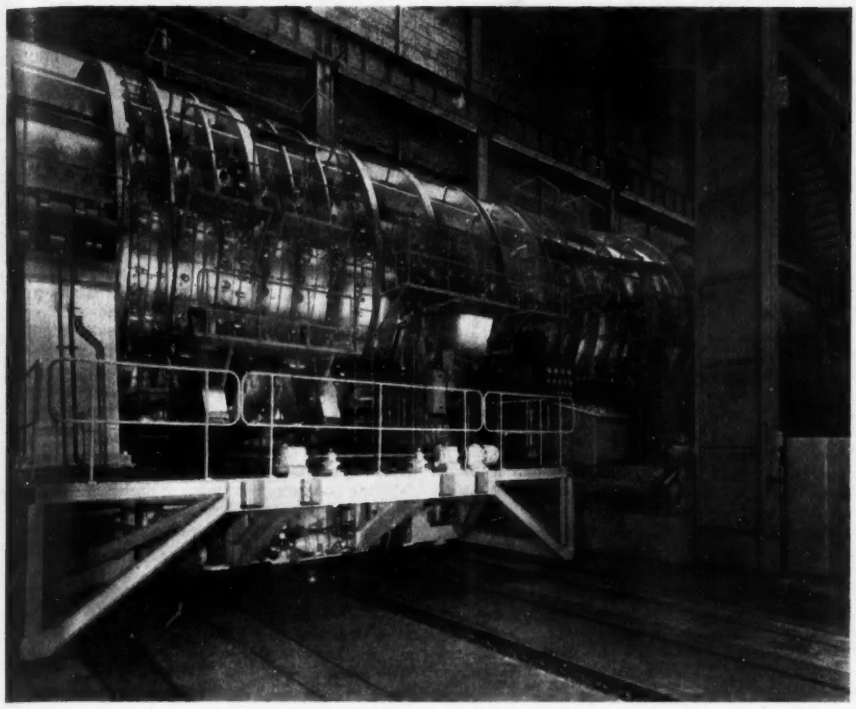


Fig. 8—Compressor of the 8ft by 8ft wind tunnel with, in the foreground, the trolley conveying the high-pressure stages: the nuts securing individual blades in the six rows of stators can be seen. The removable section weighs, complete, about 600 tons

trucks are guided during traversing, was found to be level to $^{1}/_{32}$in, straight to within $^{1}/_{64}$in, and vertical to within 0·75 minutes of arc. This thrust rail also receives the aerodynamic thrust loads from the rotor, via the bearing housing and the main truck, which can rise to 90 tons maximum ; it can be seen in the foreground of Fig. 8.

The truck is traversed by a 3 h.p. induction motor and reduction gearbox located at the side of the rail and driving through a pinion on to a rack. The maximum speed of traversing is 4ft per minute, which is automatically reduced as the truck approaches the end of its travel by limit switches which introduce resistance into the motor rotor circuit. Accurate positioning of the truck is possible by use of this simple control system combined with limit switches and indicating lamps.

Either truck is held rigidly in the running position by four pairs of clamps, each pair being driven through high reduction gears by a reversible electric motor.

Before the truck can be traversed it must be jacked up through a distance of $\frac{1}{4}$in, on to its wheels which are relieved of load when the truck is in stream. The truck jacking operation is accomplished hydraulically by a non-reversible motor-driven oil pump and arranged so that two jacks move together to keep the truck level. The h.p. section and its truck weigh 600 tons ; the dummy casing and its truck weigh 96 tons.

The operations for exchanging the h.p. and dummy sections are carried out from a control desk adjacent to the compressor, and the sequence of operations is fully interlocked to ensure that each operation is successfully completed before the next is started.

To enable the h.p. stages and dummy casing to be interchanged, the joints between the moving portions and the fixed portions of the l.p. compressor and tunnel structure have to be broken. For this two quick-release rubber-to-metal inflatable circumferential seals have been provided. A keystone section rubber ring is fitted at each end of the h.p. and dummy section casings. Against each of these, when in stream, is forced a steel ring of 18ft diameter which is rubber bonded to two similar rings of 18ft 10in diameter and 16ft 3in diameter, which are bolted to an annular water box. One water box is bolted to the tunnel structure at the h.p. compressor outlet and the other is bolted to the l.p. compressor outlet bearing casing. By pressurising the water box the centre ring moves axially until it presses against the sealing rubber strip. The water pressure is maintained at 60 lb per square inch gauge by a make-up pump automatically controlled from a pressure switch, and another pump circulates the water via a small cooler. To accommodate volumetric changes in the system due to thermal expansion of the casings an air piston type of accumulator is incorporated in the seal circuit. The system is arranged so that in the event of pressure failure in the lines outside the seals, spring-loaded valves close and lock the seals in the extended position, thus preventing an uncontrolled opening of the tunnel circuit.

The rubber moulding and curing of the casing seals was carried out on site after the technique had been established at works on a smaller (approximately 6ft diameter) five-ring seal. The design of this seal was arranged so that, when no further information was required from the model produced, the two outer rings were removed and the remaining steel/rubber/steel assembly used as a flexible joint between the shaft steel tube (through which the compressor drive shaft enters the tunnel structure) and the l.p. compressor inlet bearing pedestal.

The l.p. and h.p. rotors are each mounted in two white metal journal bearings with a fixed pad thrust bearing combined with the l.p. inlet and the h.p. outlet end journal. On starting, each journal is initially hydraulically jacked and the main lubricating oil to both journal and thrust bearing is supplied by an electric flood pump. There is also a mechanical flood pump driven from the main drive gearbox through a layshaft system. The electrically driven pump cuts out when the compressor speed has risen to 200 r.p.m. and cuts in again when the speed falls below 200 r.p.m., or in the event of failure of the shaft driven pump. Jacking oil is also brought in again as speed falls.

The lubricating oil system is fed from a tank under the l.p. compressor and from a similar tank under the h.p. compressor to which it is connected. Quick release, self-sealing couplings enable the h.p. connection to be broken and the h.p. system to retain the oil when the truck is jacked and the h.p. compressor and dummy casing are interchanged.

Also fed from this system is the shaft seal. The compressor drive shaft passes through the tunnel shell, and to prevent air leakage between the tunnel and atmosphere oil is supplied by an electrically driven pump to flood the annulus between the shaft and the shaft seal housing in the drive shaft tube. Part of the oil to the shaft seal flows along the shaft into the l.p. inlet bearing housing chamber and back into the l.p. oil tank reservoir, but part flows in the opposite direction along the shaft and back to the main lubricating oil reservoir. As this oil is lost to the compressor lubricating system an electrically driven make-up pump operating automatically from float switches in the low-pressure compressor oil tank maintains the correct oil level in both l.p. and h.p. oil tanks.

Oil mist or vapour must not be allowed to leak into the tunnel air stream, so the bearing labyrinth glands are packed with dry air bled from the tunnel and the bearing system is scavenged so that it is always below tunnel pressure ; thus, dry air is drawn into the bearing

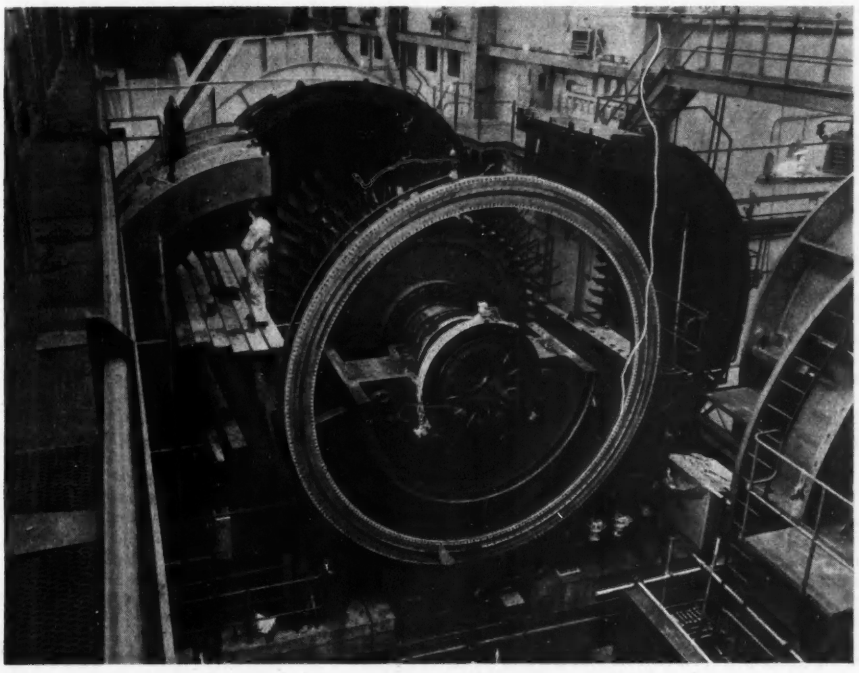


Fig. 9—Low-pressure stages of compressor of 8ft by 8ft tunnel: the high-pressure stages have been moved out of circuit to the right

oil drain chambers carrying with it the oil mist from the bearings. The necessary vacuum in the oil tanks is maintained by a vacuum pump or scavenge evacuator of the rotating vane pattern, which discharges the air/oil vapour to atmosphere via a cooler and an oil separator. When tunnel pressure rises above atmospheric a non-return valve in the evacuator by-pass line opens and flow is established to atmosphere through an orifice. The evacuator is shut down by a pressure switch when tunnel pressure reaches 17·8 lb per square inch absolute and the leakage from the tunnel through the compressor glands is then controlled by the orifice only. To prevent "motoring" of the evacuator and hence uncontrolled air flow, a solenoid valve in the suction connection to the evacuator also closes at this pressure.

With tunnel operating pressures varying between 1·47 and 60 lb per square inch absolute at compressor outlet, and with the bearing system scavenged so that all leaks are inwards through the glands from the tunnel, the pressure of the oil in the tanks under the l.p. and h.p. compressors varies over a wide range and can fall as low as 0·9 lb per square inch absolute. The mechanically and electrically driven flood pumps drawing from these tanks are approximately 9ft below the oil level, but even so, at the low tunnel densities the effective pump suction condition can fall to 22in Hg vacuum. Commissioning runs have disclosed that it is essential to have good venting of the lubricating oil system from the pump to the lubricating oil tank to release entrained air and avoid cavitation.

The compressor is directly coupled to a 68,000 h.p., eight-pole, synchronous motor, which in turn is connected through a single stage, double helical gearbox to two 6000 h.p. d.c. motors in tandem. (The shaft length from h.p. compressor outlet to the d.c. motor barring gear coupling is 145ft.) The two d.c. motors are energised in a simple series loop by two similar machines acting as generators, all four having been obtained from Germany after the war, driven by a 14,000 h.p., 11kV, ten-pole, synchronous motor which is reactor started under automatic sequence control. The shaft-driven exciter provides fixed excitation arranged to give unity power factor at full load.

The 14,000 h.p. motor generator set, the main a.c. motor and the d.c. motors, and the main gearbox, have separate lubricating oil systems similar to that for the main compressor, with jacking of each journal bearing (with the exception of the gearbox), electrical flood pumps for starting, stopping and emergency use, and "mechanical" flood pumps, shaft-driven from the main gearbox. A spare bearing set for the main motor was displayed: the bearings had been hand scraped.

In view of the troubles with banding and coil movement experienced with similar machines operating on the 3ft by 3ft wind tunnel, the armatures of all four d.c. German machines were rewound before being put into service.

Under reduced load conditions the compressor can be driven by the d.c. machines alone over the full designed speed range of 150/750 r.p.m. with the 68,000 h.p. motor electrically disconnected. For high power working the 68,000 h.p. motor can be run at a fixed speed of 750 r.p.m. from the grid supply, with the d.c. motors acting as pony motors to run the compressor up to synchronising speed, and contributing 12,000 h.p. to the drive.

Both a.c. and d.c. motors are used for variable speed working by connecting the 68,000 h.p. motor to a variable frequency supply which is available from the two 20MW gas turbine generating sets.

Facilities for both hand and automatic control of speed are provided, the design accuracy of the automatic control system being 0·1 per cent of set speed. The automatic control servo system is based on voltage comparison in which the reference voltage (the selected speed) is obtained from a special spirally-wound potentiometer which is supplied from a stabilised d.c. voltage, and the control voltage (actual speed) is obtained from the rectified output of an inductor type tacho-generator which has been specially developed for this application. The tacho-generator is driven from the main drive gearbox and it has been found necessary to mount it in a temperature controlled box for stability of output.

The error signal is fed through an electronic amplifier to an auxiliary field on the d.c. generator exciter which gives quick response to sudden disturbances. To limit the dependence on electronics, the amplifier output also operates the d.c. exciter main field rheostat by means of a pilot motor. Thus, under steady conditions, the d.c. generator output and, therefore, the shaft speed, is controlled by the main rheostat setting, while under transient conditions the output of the electronic system is superimposed on this setting. The voltage developed across the interpoles of one of the d.c. generators is used as the control signal for a magnetic amplifier acting on another auxiliary field of the d.c. generator exciter to provide d.c. current limitation in the main armature circuit.

When working with the variable frequency alternators, the d.c. machines operate under automatic control with either hand control or automatic control of the gas turbine. Under manual control of the gas turbines remote operation of the gas turbine fuel control valve is effected through a Selsyn link to take up major changes of load beyond the capacity of the d.c. machine. Under fully automatic control the same voltage comparison servo loop is used as for the automatic operation of the d.c. machines, but the error signal, in addition to adjusting the excitation of the d.c. generators, also controls the fuel valve setting on the gas turbines.

The English Electric Company, Ltd., was responsible for the design and construction of both the compressor and main drive, with the exception of the rewinding of the German motors and generators by Baldwin and Francis, Ltd.

Auxiliary Plant.—For pressurising the tunnel there are two three-stage centrifugal compressors delivering 36 lb/sec at a pressure ratio of 2 : 1 in parallel or 23 lb/sec at a pressure ratio of 4 : 1 in series. Charging times for the tunnel are one-quarter hour to 2 atmospheres and one hour to 4 atmospheres, and the total power of the driving motors is 3450 h.p. Two trimming compressors, each with a capacity of 2½ lb/sec at a pressure ratio of 4 : 1 are also provided.

For evacuation two sets of helical lobe positive displacement evacuators are used, each with a capacity of 45,000 cubic feet per minute, which together can evacuate the tunnel to $^1/_{10}$ atmospheres in 11·1 minutes. Each set consists of two l.p. machines in parallel and one h.p., and the total power for the two sets is 5270 h.p. These are the largest Howden-Lysholm compressors yet built, the l.p. rotors being 49in long and 24in in diameter. The four l.p. compressors can also be run in parallel to drive a 13in by 13in tunnel which was built as a $^1/_7$ scale model to determine the optimum positions for the moving walls of the supersonic diffuser.

All air admitted to the tunnel is dried to a humidity less than 0·0002 lb moisture per pound air. The drying is done partly by cooling, by means of refrigerated brine, and partly by silica gel adsorbers. Separate adsorbers are provided for the charging and trimming compressors, and each adsorber includes two vessels, one of which can be used while the other is being regenerated. The total quantity of silica gel is about 10 tons.

While the tunnel is running the dryness of the air is maintained by circulating a small flow of dried air in and out of the circuit by means of a trimming compressor and an evacuator, an arrangement which also allows a precise control of tunnel pressure. This air is fed into and drawn out of the tunnel circuit at the trailing and leading edges of the aerofoil struts supporting the compressor tail fairing, and to avoid any irregularities in the flow the incoming air is first heated to the temperature of the tunnel air at that part of the circuit, which may be up to 160 deg. Cent. Eleven induced draught cooling towers are used to dissipate the heat from the main tunnel cooler, the gas turbine coolers, and numerous smaller coolers used on the plant. These towers can dissipate a total of about 200,000 h.p. The tubes of the tunnel cooler being mild steel, a small dosing plant injects sodium hexa-meta phosphate into the water as a corrosion inhibitor.

Approval to proceed with this tunnel was given in August, 1949; it has recently been completed and is expected to be in service shortly.

(To be continued)

International Congress on Ports and Waterways

No. I

THE International Navigation Congress was opened on Monday last at the Institution of Civil Engineers by H.R.H. the Duke of Edinburgh. The congress is now in progress and is being attended by about a thousand delegates. It is the nineteenth in the series of congresses organised by the Permanent International Association of Navigation Congresses, the subject matter under discussion being "related to port and inland waterway transport and engineering." The congress will remain in session until July 16, and is organised in the way which has become customary for international meetings of this kind. Apart from the technical sessions, delegates will have the chance to visit various places of special interest to them around London, as well as indulging in lighter visits, official receptions, and so on. After the congress, there will be tours to South Wales, Manchester and Liverpool, the Humber and Tyne, Scotland, Bristol and Avonmouth, and a tour of inland waterways.

A brief review of the technical matters under discussion at the nineteenth congress is given hereunder. The printed papers are, again as is usual in a congress of this nature, somewhat voluminous, and so we can only hope to give a general idea of the subjects in a condensed manner. The principal division is into Section I dealing with inland navigation, and Section II, on ocean navigation.

Inland Navigation

The papers discussing inland navigation are grouped under three "questions" and three "communications." In the official congress language the questions are: Question 1: the role of inland waterway transport and its relation to other modes of transport with a view to furthering the economic development of the various countries. Question 2: evolution of types of propulsion and control of single craft and trains of barges on rivers and canals; comparison between self-propelled vessels and others. Question 3: new means of utilising the hydraulic energy of navigable waterways; their interference with navigation and their influence on the design and construction of all structures concerned, with special regard to movable barrages (dams).

The "communications" in Section I are as follows:—Communication 1: means of dealing with large differences in head in order to facilitate the passage of vessels on inland waterways; comparison of the various solutions from the technical and economic points of view; works constructed and contemplated; results obtained. Communication 2: means of making watertight the beds and dykes of navigable canals and rivers. Communication 3 (which is common to Sections I and II): influence of ice on navigable waterways and on sea and inland ports; means of overcoming its effects.

The Role of Inland Waterways

The first question of Section I consists, in effect, of eleven reports, each of which reviews the scope of inland waterways in one particular country. The U.S.A., Canada, the U.S.S.R., and various European countries are treated in this way. Most of the canal systems are active and

are developing. No other country seems to have suffered such a decline as Great Britain in canal transport. One parallel, however, to the extensive abandonment of obsolete canals contemplated in this country is to be found in Sweden, where certain canals are being enlarged to take sea-going ships, so that "inland navigation" in the true sense is being superseded. But the conditions are different in each of the countries concerned, and for fuller understanding of the relevant factors the original papers should be consulted.

Propulsion and Control

In Question 2, also, each of the papers tend to be a series of reviews, each of history, practice and current trends, in the particular country concerned. On European rivers the self-propelled vessel appears to be increasingly gaining favour over the dumb barge, because of its greater speed. However, economic advantage lies with the dumb barge, and on such waterways as in the Belgian Congo and the U.S.A., the parallel trend is in the use of streamlined or integrated tows, which aim at the advantage in speed without loss of flexibility for utilisation offered by the dumb barge.

Hydro-Electric Energy

For the third question in Section I, which relates to power generation in conjunction with navigation, and the way hydraulic regulating structures affect navigation, we have taken an abstract from the general report, which was written for the congress by Mr. R. D. Gwyther, M.I.C.E., of Messrs. Coode and Partners.

Whether a river, from its source to its mouth, is confined to one state or country in its course or whether it passes through several states or countries, the river is assumed to be free to all and from this it surely follows that the benefits and rights of those living on its banks and those using the river should not interfere with the benefits or rights of others. Flood control may benefit some and inundate others, irrigation may aid some and adversely affect others in the lower reaches. Towns and factories may pollute the river, power projects may alter levels and interfere with navigation. From these few examples it is obvious that every project bristles with problems and that a very great amount of preliminary consultation and discussions must ensue before agreement is arrived at and a scheme can be formulated. All the papers presented to the congress bear this out and it appears that the first conclusion reached is that the control of a river should be vested in an authority upon which all interests are represented.

Professor H. Wittmann and Dr. E. h. H. Fuchs in the paper from West Germany remark that power development now involves rivers previously only used for navigation, and describe the measures taken to reduce the effect that the operation of hydro-electric installations have on navigation, pointing out that although navigation must be maintained it should not be regarded as the sole criterion. The filling and emptying of navigation locks in short periods of time could influence the effective running of a power station, also the running of turbines at peak loads, or the sudden shedding of load, could likewise affect safe shipping conditions, particularly downstream of the dam. The results of a series of model tests, to a scale of 1 in 55, carried out at the Jochenstein power station on the Danube on a model barge approaching upstream of the lock, and also when moored in the lock, to ascertain the effects on the waves and forces, created by surges, by reducing the time of opening sluices, lengthening, the time of throttling down the turbine, and increasing the quantity of water passed through the turbine with and without altering the sluices, are given in considerable detail. Details are also given of a series of investigations by Messrs. Voith on the quantity of water which can be passed through a Kaplan turbine, without load, with the introduction of air to damp down resulting vibrations, made first on a model of scale 1 in 10·3, and later on the actual turbines supplied by Messrs. Voith at Jochenstein power station with a tethered barge of 720 tons gross weight. The experiments with the model and the actual tests at the power station confirm that the adverse effects arising from surges can be simply and safely reduced by a combination of turbine control and lowering of sluices. Normally the power and navigation demands are balanced sufficiently to avoid interference with navigation.

From the accounts of the projects given by the authors of the papers from different countries it is difficult to formulate any general conclusions. It would appear, however, that with large differences of head single locking has its advantages.

In rivers with small gradients a series of installations with low heads are generally favourable to navigation and modern types of generators such as the "bulb set" described in the paper from France may further developments in power production where navigation and low heads are concerned.

There are many varieties of movable dams ranging from the ordinary lift or submersible sluice gates, hook gates, rolling gates with or without regulating flaps, radial gates, sector gates, drum gates, spillway flaps, &c. Early types gave valuable aid to navigation on several rivers at the beginning of the century such as the extensive system of movable dams on the River Ohio, which includes the well-known Mervill Dam, constructed to maintain slack water for navigation, and again on the rivers Moldau and Elbe between Prague and Aussig. It would be of interest to know if, after more than fifty years, these are still serving the same purpose. The only mention of the use of flaps occurs in the paper from France.

Perhaps some indication as to the safe velocities in approach channels to navigation locks might be suggested, together with the maximum speed of filling and emptying locks. To us in this country a rise of as much as 3m per minute is remarkable. There seems to be no general practice in regard to the method of filling navigation locks though possibly more locks are filled through culverts in the walls than by direct flow through the gates.

Large Differences in Head

The five papers in Communication No. 1 of Section I are, again, conveniently reviewed by abstracting from the general report, which in this case is the work of Mr. C. A. Wilson, M.I.C.E.

The Czechoslovak paper sets out some of the considerations, with special reference to the filling and emptying times, governing the design of large navigation locks contemplated to be constructed together with hydro-power plants, on the Czechoslovak and boundary parts of the river Danube.

The hydraulic computations of the filling and emptying system for a total length of lock chamber of 285m, width 26m and lift of 17·55m are given in detail together with the method of computation, the results being set out in a table. The paper is accompanied by five plans of double locks showing alternative filling systems and one diagram giving a graphic representation of the table of results of computations.

A French author, Monsieur Dumas in his detailed and informative paper considers that it is difficult to declare *a priori* in favour of the absolute superiority of locks to lifts up to differences of level of 30m, but for differences of level above 30m, it would seem that in most cases lifts must prevail over locks.

The paper commences with a description of the Fontinettes canal lift on the Newfosse Canal, built in 1887 to overcome the difference in level of 13m at Arques between the two reaches of the canalised Lys, on the one hand, and the canalised Aa on the other. The aim of recent French lock design has been to reduce locking time to a minimum. The difference in level to be overcome ranges from 16m to 26m, the lock length being 185m and width 25m. Details of the construction of the filling and emptying systems of a number of locks are given, together with the difficulties met with and how these were solved, and the modifications made while construction was in progress.

In the case of differences in level over, say, 10m the filling and emptying of the lock chamber have to be carried out with the aid of a series of subsidiary culverts leading into the chamber, at carefully selected points, the lock chamber being separated from the upstream and downstream reaches by flood gates installed in the main culverts. The effect of differing the positioning of the openings to the chamber as affecting turbulence in the lock is discussed and the results of experiments on a scale model carried out in the case of new high-lift locks built after 1946 is given. The author gives reasons supporting the grouping of openings in the middle section of the lock and stresses the importance of design of the culverts, further reduction in turbulence being obtained by using perforated slabs over the outlets where placed in the chamber invert. The author instances the case of St. Pierre lock on the Rhone canal at Donzere-Mondragon, which has a head of 26m.

Monsieur Florentine Briones gives a most interesting account of the creation of what might be described as the first river waterway for navigation in Spain, a country where the contours of the rivers and regimes are such that only in the Ebro and the Guadalquiver are there possibilities of establishing navigation. The paper gives an account of the regulation works commenced some time ago and now being carried out on the River Guadalquiver, but which are not expected to be completed for some years. The coastal section of the River Guadalquiver is navigable for some 90km from the Atlantic to the port of Seville and the works now under construction cover the 200km to Cordova, the difference in level to be overcome being 90m. Broadly the work divides into three sections, the lower 73km long where the river is canalised, the difference in level of 18·75m being covered by two locks, this section being already completed. The middle section 51km, difference in level 28·25m covered by three locks, which will be in lateral canal and is now under construction; and the upper section 76km difference in level 43m covered by five locks and which is still in the planning stage.

Mr. Martin E. Nelson in his very complete paper gives a detailed review of recent United States practice and research into the principles and practical solutions to problems involved in the design and operation of hydraulic systems for filling and emptying chamber locks.

The most common type of hydraulic system used in the United States locks and the one kept primarily in view throughout the paper utilises a longitudinal culvert in each lock wall which conveys the water from the upper pool into the lock chamber through short lateral ports or through lateral conduits in the lock floor with short ports in their side walls or roof slabs. Other types of filling systems admit water from the upper pool into the upstream end of the lock chamber through (1) loop culverts around the upper service gate, (2) through ports in the service gate or in the service gate sill, (3) over a submerged service gate, or (4) between or around sector service gates. End filling is being used to some extent in current design of locks to supplement wall culvert filling systems. United States locks rarely have to be operated under a restricted water supply; consequently, economy basins are not required.

In high-lift locks the serious problem of negative pressure, vibration, cavitation and excessive loading on the valves during the opening cycle can be minimised by streamlining the structural members, increasing the dead weight of the valves, and locating them at the lowest practicable level.

Mr. Nelson considers that there is a need for further research not only in the basic hydraulics involved in filling and emptying systems, but also in operational characteristics for higher lifts and larger lock chambers. Also more information is needed as to permissible hawser pull and degree of turbulence; and the causes and means of preventing vertical action at intakes and cavitation at valves should be explored more thoroughly. With further increases in lift it may be necessary to depart radically from the conventional valve design in order to combat the effects of flow contraction, high velocity and sub-atmospheric pressures.

In their joint report consultants Heinrich Rütjerodt and Dr.-Ing. Marten Arens express the view that in cases where the foundation soil is not able to withstand very variable pressures, such as those which arise under the bed of a lock, the differences in the levels of the successive reaches of a waterway are best cleared by canal lifts. Their contribution is therefore confined

to lifts with perpendicular hoists in open troughs filled with water.

Of the more recent proposals for lifts on new waterways only two have so far proved their practical utility ; the lift with axial floaters and the lift with counterweights. These systems are the basis of the plans now under way for a second lift at Henrichenburg and for the three-stage lift on the Main-Danube Canal (with hoists of 28m to 46m). While the authors do not deal with the design and construction of the three lifts at Henrichenburg, Niederfinow and Rothensee, they give informative and interesting details of their operation and maintenance.

The one feature which all five papers have in common is a participation in the use of models in studying not only flow problems of hydraulic systems for filling and emptying a lock, but also in the case of the Niederfinow Lift of the drive system where the scale model was one-fifth the actual size. The American paper gives a very full account of the test equipment and methods used in the various laboratories and which are believed to be fairly well standardised. It now appears to be the practice to carry out hydraulic model tests for each individual lock before putting the project in hand. The scale ratio generally used is one-twenty-fifth for the complete tests and one-twentieth for valve tests. Model ships of the usual displacement operating on the waterway are used in the study of hawser pull conditions. Monsieur Dumas mentions also the practical study of the eddy curve in the reaches during filling or during emptying and records the results of tests carried out at selected locks. The need for model tests in all large projects is now so generally recognised that no further comment is necessary.

The object of the above tests, namely, speed and safety in the filling and emptying of lock chambers, was dealt with at some length in the papers from America and France; the question was also discussed at the seventeenth congress at Lisbon in 1949 ; in the communication under review the matter is relative to the total time of surmounting a difference in head. Mr. Martin puts this as related to capital investment, one minute saving in lockage time being equivalent to 60,000 dollars. Monsieur Dumas contrasts the time taken for a complete cycle of operations for Fontinettes lift and certain locks, and goes on to formulate the main advantages and drawbacks respectively of canal lifts and locks with a deep drop up to approximately 30m ; briefly these are as follows :—

(1) For lift, no disturbance in lock chamber or in reaches on either side.

(2) For lock, using suitable methods of filling and emptying, almost complete tranquillity in the lock chamber can be achieved, and harmful occurrences arising outside suppressed.

(3) Modern lifts for drops up to at least 30m can have locking times comparable with locks for capacity 1500 to 2000 tons per locking without the boats in the chamber or in the approaches being disturbed.

(4) For the same depth of drop and capacity a canal lift would not only involve much more initial expenditure than would a lock, but would also cost more to operate and maintain ; in addition, greater precautions against the risk of damage would be required.

(5) For a modern lock with centralised controls operating labour and maintenance outlay is at a minimum.

(6) Canal lifts have a considerable saving in the consumption of water over a lock where economy basins are installed.

Watertightness of Canal and River Beds

Here, again, the nine papers presented to the congress give reviews of national practice in this subject, and of new developments in the countries concerned. However, the French author gives a discussion which amounts to an important treatise on the general principles of percolation and the advantages of the various methods used to stop it. He also gives an account of the circumstances best suited to each class of sealing, and some indications of relative cost.

Ice

Eleven papers discuss the problem of ice in navigable waterways and in ports. Practically all aspects of this subject are touched upon. A particularly lengthy and comprehensive study is given by the Russian authors. Remarkable results have been achieved in combating the severe winter conditions in Russian waterways, one of the most noteworthy measures being the introduction of an ice-forecasting service.

(To be continued)

Conference on Automatic Production

A conference organised by the Institution of Production Engineers and having as its theme " Automatic Production—Change and Control " was held at Harrogate from June 30 to July 3 last. At this conference sixteen papers provided the basis of group discussions which were broadly arranged in four sections covering the plan of production, the programming of production, the production process, and the people in production. Before the various groups separated for their discussions the plenary sessions were addressed by the Earl of Halsbury on " The Administration of Modern Production " and Mr. E. W. Hancock on the subject of the small firm.

In opening his address at the first session, Lord Halsbury pointed out that the conference was concerned with change and control, i.e. the administration of the most modern production. In administration something was always being changed, or by control being prevented from changing spontaneously into something regarded as undesirable. Change and control were the heart of administration, and administrators from of old had blended experience with intuition. In administration, as in many other fields, we were going through a phase of accelerated progress. In such cases people frequently mistook a transient acceleration for a permanent one and wondered uneasily what would happen if it kept up for ever. They also tended to confuse a transient acceleration with a discontinuity and evolution with revolution. Lord Halsbury did not believe that we were undergoing a revolution though the course of evolution had accelerated. The intuitively clever person would not lose his place in society for it would take more than computers and automation to change the pattern of culture. The facilities available to the basic culture pattern for exploitation would be greatly extended, he considered, and rationality would encroach markedly upon the preserves of intuition.

In the first session the four groups discussed the following papers :—" The Effects of Automation on Management Organisational Principles and Practices," by Dr. Lillian Gilbreth ; " Control and Communication—A Management Concept of Cybernetics," by Miss Joan Woodward ; " The Electric Computer as a Tool of Planning and Control," by Mr. A. O. Mann, and " The Cost of Automation," by Mr. F. T. Hunter.

In opening her paper, Miss Woodward said that the title it had been given was somewhat misleading as the problem she was going to discuss was the relationship between technical change and management structure. The paper was based upon the findings of a research project undertaken at the South East Essex Technical College between 1953 and 1956, under the sponsorship of D.S.I.R. Medical Research Council Joint Committee on Human Relations. Under this project some 100 firms, of widely different sizes and forms of production, co-operated in providing the College with information about their objectives and background history, and the way in which they were organised and operated.

In his paper on the cost of automation, Mr. F. T. Hunter said that it would seem unarguable that, no matter what the opposition, manufacturing and control techniques would change rapidly in the next few years, and that more and more reliance would be placed on automatic means of production. Mr. Hunter discussed the problems arising from automation largely from the angle of a cost accountant, and concluded by saying that he had attempted to suggest some of the problems which would affect the cost accountant, without attempting to produce precise solutions, most of which would inevitably at present be guesses.

At the second session in a discussion group concerned broadly with the programming of production, Mr. W. J. Kease presented one of the papers which was entitled " Computer-Assisted Production Control." This paper dealt with the production control department of a large heavy road vehicle manufacturing concern, with particular reference to the introduction of an electronic computing machine into the routine procedures of co-ordinating and regulating the output. Another paper, by Dr. S. Eilon, on " Scheduling for Batch Production," showed how computation of lot sizes could be applied to problems arising from scheduling of batch production. An analysis described offered a systematic procedure pointing out the decisive issues involved and the steps that had to be taken. It also provided a comparatively simple method for formulating a final satisfactory production schedule, as well as a useful guide when changes in the schedule had to be introduced. One of the main assumptions in this analysis was that manufacture of one product followed the completion of a batch of another product, with no overlap of production times. The problems arising when simultaneous manufacture of various products took place were far more complicated and no attempt at a solution was made in the paper, but, it was pointed out, many such cases might sucessfully be treated as approximations by the methods outlined.

In a paper " Product Design for Automation," the author, Mr. D. L. Johnston, pointed out that some of the economic, social and technical problems of automation had received much attention and were now better understood. What had not yet been discussed adequately enough was the impact of automation on the design of products, rather than the actual usage and effect of automated plant.

In product design much greater use should be made of " simplification, specialisation and standardisation " internationally, together with a modular approach to the subdivision of machines and structures. This, said Mr. Johnston, economised in design effort.

Under-developed countries could advance very rapidly by drawing selectively upon the experience of the more advanced countries, whereby they could enjoy a foresight of what would be available to them in the future. Thus, they could " leap-frog " some of our pioneer mistakes, and select advanced and economical basic product designs adequate to their requirements. Such designs had a long life before they became obsolete.

Another paper discussed in the same session also emphasised the importance of design for automation. It was entitled " Simplification and Standardisation for Automation " and was presented by Mr. E. G. Brisch and Mr. R. S. Geoghegan. Early in this paper it was stressed that automation, whether expressed in the form of electronically controlled plant or in the form of transfer machines, would only yield the optimum results when, for the application under consideration, the variety of parts, materials and even tools had been reduced to a minimum. Simplification, i.e. the process of reducing the number of varieties made or procured, and standardisation, the process of securing the maximum utilisation of preferred varieties having agreed standards of performance, quality, composition or dimensions, were essential requirements for the automatic factory. The many advantages arising from automation would be lost unless a clearly defined policy of simplification and standardisation had been laid down and the means devised to ensure its effective implementation and application. The very concept of the automatic factory would be greatly minimised or even destroyed if an excessive variety of processes and operations were necessary.

The second plenary session of the conference heard an address by Mr. E. W. Hancock before the discussion groups were formed. He contended that small firms were closely concerned with all aspects of the conference, as by virtue of their specialised products supplied to the whole of the country or an industry they had a volume which was likely to justify automatic production, both on batch or flow methods. Without the small firm automatic production would be in serious jeopardy, he said, and such firms could and were using the techniques of the production engineer on batch or flow production to the benefit of the national economy.

Acorn Bank Opencast Coal Site

From the 440-acre Acorn Bank site, near Bedlington, Northumberland, a yield of 5,000,000 tons is expected at the end of seven years of working. This involves the delivery of 16,500 tons of coal per week and this amount is now being produced by the plant engaged.

IN our issue of June 22 of last year we recorded that Costain Mining, Ltd., had been awarded the contract to mine the Acorn Bank site and gave a general account of the initial work following a visit to the site. There are three seams of coal, named High Main, Top Grey and Bottom Grey, within the 440-acre site, the lowest seam ranging in depth from 230ft in the north-east corner to 100ft in the west. The method adopted for working the site was to make an initial box cut some 3200ft long, along the eastern boundary, by 100ft wide and 230ft deep, and then to progress westwards by making parallel cuts 80ft wide and filling in the worked area with spoil from the cut being worked. This makes for the rapid restoration of the ground for agricultural purposes, which was a clause in the contract, the fulfilment of which precluded the use of the permanent ramp system and called for a different system of operation. Ruston-Bucyrus electric shovels of 5 cubic yards capacity are employed to remove the overburden down to 140ft above the lowest seam after 12in of topsoil and 3ft of subsoil have been removed to the storage area. The photographs which we reproduce give an aerial view of the site as at present being worked and show operations for removing overburden and coal.

The initial removal of the overburden forms a high wall on which are mounted two 25-yard Bucyrus-Erie draglines, four 13-ton electric derricks, other equipment involved including three 5-yard Ruston-Bucyrus electric shovels, a fleet of 22-ton Euclid rear-dump trucks, and a number of 2-yard and 1-yard shovels, together with rotary air blast drills. Other plant in use includes bulldozers and scrapers, and a "Traxcavator" fitted with a hydraulic back ripper.

The draglines, which work one at either end of the cut, remove the overburden prepared by rotary blast air drills, down to the coal seam, and deposit the spoil in a worked-out cut. Coal from the lower seams is raised in grab-loaded, 10-ton skips to the high wall and loaded into 40-ton, bottom-dump semi-trailers, which were described in our earlier article, by the electric derrick cranes. These are high-speed units, manufactured by Butters Brothers and Co., Ltd., mounted on three bogies at 60ft centres, and fitted with four single flanged wheels set for a rail gauge of 5ft 6in. Two of the bogies carry 60 tons of ballast. The maximum load is 13 tons, consisting of a skip weighing 3 tons and having a capacity of 10 tons of coal, which the derrick can raise at 120ft per minute, the other operational speeds being slewing at 450ft per minute and luffing at 60ft per minute. Power for these movements is supplied by motors of 180, 35 and 75 b.h.p. respectively. The maximum working radius at full load is 140ft and the operator's cabin is located in the top section of the mast to provide the operator with a clear view of the skip in all working positions. A bulldozer is employed to move the derrick from one position to another and, to enable the direction of travel to be changed through 90 deg., each bogie is fitted with four 25-ton hydraulic jacks which raise the bogies and allow the wheel housings to be rotated.

Additional coal is being mined from beyond the area being worked at the site by the introduction of horizontal augering, using a Joy coal auger, and to date approximately 500 tons of coal have been recovered by this method. The auger is mounted on a steel frame having small diameter single flanged wheels set for 3ft 6in rail gauge and a hydraulic jack fitted at each corner for levelling purposes. Cutting of the coal is by a 30in diameter head fitted with eighteen tungsten carbide tipped bits and having a pilot drill with eight finger bits in the centre. The bits are fed into the coal seam by a hydraulically operated rotating ram which travels a distance of between 4ft to 6ft. An electric motor supplies power through a twin disc clutch for rotational purposes and also operates the pump through a belt drive. The length of each auger flight is 48in and the horizontal holes are drilled at the rate of 1ft per minute for a distance of 60ft and at about 3ft centres. Each hole yields about 12 tons of coal, which is loaded by a small mobile conveyor into trucks.

The private road, which, as we noted last year had been built to facilitate the hauling of coal to the screens, consists of a 5ft thickness of sandstone which has been consolidated under traffic. It has now been surfaced with 3in of whinstone rolled and blended with ¾in of quarry rejects and topped with a wearing surface of 3in of tarmac to bring it to a standard comparable with a public highway. A work study unit is engaged in obtaining and correlating the data necessary

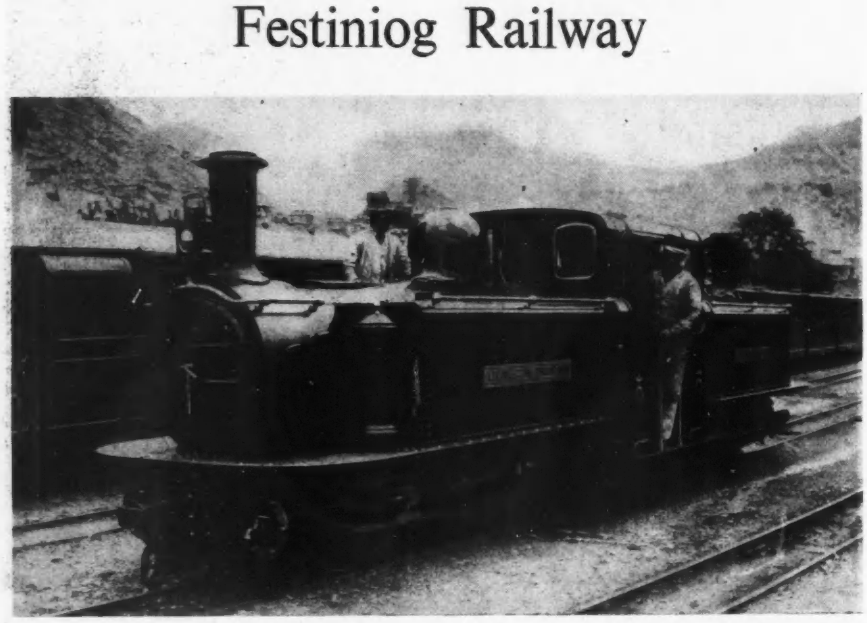
Aerial view from the north of the operational part of the site. In the centre can be seen two of the derricks, while in the left foreground is a Bucyrus-Erie dragline on the low wall

Opencast site operations ; showing, to the right, a Bucyrus-Erie dragline removing overburden and to the left a derrick loading coal into a 40-ton bottom dump semi-trailer by grab

for ensuring that the equipment is operated at peak efficiency and contributing to the economic working of the site. With the eighth cut now being worked all operations are closely co-ordinated and recently the weekly production achieved a record figure of 20,800 tons. At the present rate of working a new "cut" is formed every six weeks and the fleet removes about 180,000 tons of overburden each week. To date, 21,000,000 cubic yards have been dug, the coal produced being720,000 tons with the highest day's output reaching a total of 4016 tons. Work continues night and day with the draglines working eight-hour shifts and with the remainder of the site work being carried out in two twelve-hour shifts.

Staff and administrative offices on the site are housed in a Costain standard accommodation unit. A central corridor 5ft wide with offices 15ft wide on each side form the general design, which includes 11in cavity brick gable walls and outside walls consisting of a 3ft high plinth of 11in cavity brick surmounted by continuous standard windows, having one opening light, set on a continuous concrete sill. Cross stiffening is by 4½in brick partition walls or by special precast concrete posts where long office units are required. Timber joists of 7in by 2in scantling and at 2ft centres support the roof consisting of 2in wood wool slab with a bituminous felt on top and including an integral gutter. The floor is formed of 8in of hardcore and 3in of rough concrete topped by 2in of screeding, there being no dampproof membranes. For heating purposes electrical cable is built into the floor and the heating is operated by a time clock device.

Festiniog Railway



The "Taliesin" at Blaenau Festiniog *circa* 1890. The locomotive was known as "Livingston Thompson" at the time

LAST week by invitation of the English Electric Company, Ltd., we had the pleasure of visiting the Festiniog Railway in North Wales. The excuse for the visit was that the "Taliesin" locomotive would be shown to us. In reality we went to see how the band of enthusiasts that now run this railway are getting on towards its restoration to a full working service. The line, as all interested in railways will remember, runs from Portmadoc harbour on an almost continuously rising gradient of about 1 in 92 to Blaenau Festiniog, 700ft above sea level. The gauge is 2ft and the railway was originally constructed in the 'thirties of the last century to bring down slates from the quarries at Blaenau to be shipped from Portmadoc to all parts of the country. At first the trucks ran down to the harbour by gravity and were pulled up the incline by horses. But in 1863 two small 0-4-0 locomotives made by George England and Co. entered service on the line and proved capable of hauling 50-ton trains up the gradient. It was soon after their entry into service that passengers began to be carried.

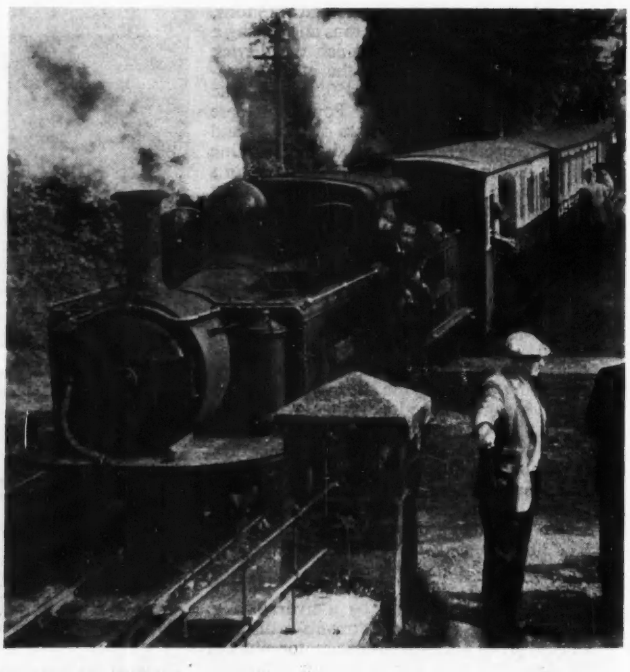
Late in the 'sixties the need for more powerful locomotives was felt and George England and Co., of New Cross, London, built for the railway the first of the Fairlie locomotives for which the railway is famous. Several such locomotives subsequently entered service, the last of which, built by the company in its own workshops near Portmadoc in 1885, was originally named "Livingston Thompson" but was renamed "Taliesin" in 1906, when a single Fairlie built by the Vulcan Foundry, Ltd., went out of service. It was this locomotive that we saw in operation and which is illustrated above in its condition *circa* 1890.

Up till 1914 the railway prospered. But after the war the slate traffic declined and gradually the line, the locomotives and all else were allowed to fall into disrepair. All passenger services ceased in September, 1939, and though thereafter a few slate trains continued to run, nothing more than minor maintenance was done. By 1946 conditions were so bad that operations were wholly suspended; the line became derelict and all its equipment, untended, was left to rot wherever it happened to be.

That might have been the end of the railway had not a group of railway enthusiasts inspected the railway in 1951 and conceived an original idea for servicing it. The Festiniog Railway Society was created and in June, 1954, acquired a controlling interest in it. Now there is a very small permanent paid railway staff, including several people who had worked on the railway before it became derelict and a much larger number of volunteers who spend as much time as they can spare working on or for the railway. The bulk of these volunteers are, as might be expected, railwaymen or ex-railwaymen. But some are just railway enthusiasts. All kinds of people are welcomed. Those with engineering skill find jobs in repairing and servicing locomotives and rolling stock and other equipment; those without skill can be found plenty to do in clearing the track. So far the railway has been opened for passenger services only as far as Penrhyndeudraeth, 3½ miles from Portmadoc, and trains only run from early in June until the end of September. Next year it is hoped to open the line as far as Tan-y-Bwlch, 7½ miles from Portmadoc. Thereafter clearance will be continued, it is hoped, eventually to Blaenau, 13¼ miles from Portmadoc. Works trains have already covered the whole line that far.

Two steam locomotives are at present in use. One of them is the small 0–4–0 locomotive already mentioned named "Prince," built in 1863 and rebuilt several times since. It has 8½in by 12in cylinders and a heating surface of 377 square feet and weighs 11 tons. The other is the Fairlie locomotive "Taliesin" originally built in 1885, with 9in by 14in cylinders, a heating surface of 887 square feet and a weight of 24 tons. It is illustrated below. Other locomotives awaiting major overhaul lie in the Boston Lodge works of the railway together with a variety of trucks and some passenger stock.

When the Society took over the line "Taliesin" was lying in the Boston Lodge works of the railway in a dilapidated and unserviceable condition. Vulcan Foundry, Ltd., of Newton-le-Willows, perhaps without fully realising what difficulties would be involved, undertook to rebuild it. The original idea was that the locomotive would be conveyed to that firm's works for repair. But when the position was surveyed this idea was found to be impracticable. No lifting appliances were available at Boston Lodge works, nor could they be brought into the works. The locomotive was, it is true, still on the rails. But its movement was prohibited by the presence of even more dilapidated stock. There was only one thing to be done. It had to be dismantled where it was. Certain parts were sent to the works of Vulcan Foundry, Ltd., for repair and new parts were made in those works. But much of the work was done at Boston Lodge and re-erection was completed there. Now the locomotive, much to the delight both of members of the Society and of passengers in trains, has re-entered service.



The rebuilt "Taliesin" on test with a passenger train at Minffordd

Tandem Particle Accelerator for United Kingdom Atomic Energy Authority

WE learn that the United Kingdom Atomic Energy Authority has invited Metropolitan-Vickers Electrical Company, Ltd., to collaborate in the design of two tandem electrostatic generators for use at the Atomic Energy Research Establishment, Harwell, and the Atomic Weapons Research Establishment, Aldermaston. The major parts of these machines will be manufactured at the company's Trafford Park Works. They will enable research to be carried out into the nuclear properties of uranium and similar elements and will enable energetic neutrons to be produced for other nuclear work.

Compared with the familiar Van de Graaff accelerator the tandem generator is novel in that acceleration is achieved in two stages. Negative hydrogen ions are first accelerated from earth potential to an energy of 6MeV. They are then fired into a "stripper," which removes the electrons from the outer shells of the atom and leaves the ions still moving in a forward direction with a net positive charge but with energy almost unchanged. The second stage of acceleration is achieved by bringing the positive ions back to earth potential, so that the total energy communicated to the ions is 12MeV. In this way, ions are accelerated to an energy twice as great as could be achieved in a single stage, whilst the insulation problems are exactly the same as in a single-stage machine for 6MeV. Generally, negative ions are more difficult to form than positive ions, and therefore the beam current in a tandem machine is smaller than in a single-stage machine, but this disadvantage is insignificant compared with the saving in insulation.

Some idea of the engineering problems involved in the design and construction of a tandem generator of this kind may be obtained from the following details. The generator is housed inside a pressure vessel 45ft high and 9ft in diameter, which contains an insulating belt mounted on pulleys some 16ft apart. The belt moves at 3000ft per minute, and electric charge sprayed on to its lower end is carried to the central terminal, where the charge is collected. The charge leaks back to earth through two potential divider chains, one going to the lower and one to the upper end of the vertical column. To reduce the danger of voltage breakdown, the spaces between the central terminal and the upper and lower ends of the column are each subdivided by 150 equipotential plates, connected to the potential divider chains at the appropriate tapping points. The accelerator tube is housed inside the "stack" of equipotential plates and passes right through the ends of the pressure vessel. The tube is subdivided by conducting rings, each connected to its corresponding equipotential plate, the aim being to limit the voltage across any one section of tube to 40kV.

Negative ions are formed in a high-frequency gas discharge and are withdrawn from the discharge by preliminary accelerating electrodes, which are designed to produce a focused beam of circular cross section and to fire this beam down the centre of the main accelerating tube. Electrons are stripped from the negative ions by passing them through an extremely thin foil inside the central terminal. On emerging at the lower end of the accelerator tube the beam traverses a magnetic field adjusted to deflect the ions through a right angle and bring the beam to a focus on the particular target under investigation.

Operation of a high-voltage electrostatic generator necessitates "pressurising" the vessel containing the accelerating electrodes. In this case the gas pressure is 250 lb per square inch, and the weight of gas in the main pressure vessel is about 2 tons. For maintenance purposes this gas must be removed and stored in suitable containers, and a considerable proportion of the cost of this kind of installation is associated with the equipment for transferring the gas from reservoirs to the pressure vessel and keeping it dry and free from atmospheric contamination.

In the equipment described, the ions may move distances of about 120ft before reaching their target, and the target area must not exceed a few millimetres in diameter. It is necessary, therefore, to maintain a very high vacuum throughout the entire ion path and accurately to control all the accelerating and deflecting fields. The accelerator tube is pumped at the top and bottom and, via a by-pass tube at the centre, by 14in mercury diffusion pumps with large dry-ice traps and liquid air traps in series. The accelerating, focusing and deflecting fields are controlled by electronic stabilisers to an accuracy of a few parts in 100,000.

The higher energies available from the new particle accelerators will permit the study of nuclear reactions produced by the bombardment of uranium and the transuranic elements, and a considerable advance in knowledge of the nuclear properties of these elements may be expected to result. By bombarding suitable light element targets with beams of protons and deuterons, it will be possible to produce neutrons of controllable energy in the range up to 30MeV, and to study their interaction with other nuclei. This information is basic to this country's Atomic Energy Programme, but is likely also to be of considerable fundamental interest. Other possibilities include the acceleration of heavier ions, such as those of oxygen and fluorine. It will be seen that the tandem machine will considerably extend the range of studies that can be carried out with electrostatic generators.

Gas in Industry

LAST week the Gas Council, in conjunction with the North Eastern Gas Board, organised a visit to the Leeds area to show some of the uses of town gas in the works of large consumers. During this visit interesting demonstrations were given, at the Leeds headquarters of the board, of a new design of "jet burner," which has been developed in the board's laboratories, and enables the selective local heating of parts to temperatures up to 1750 deg. Cent. at very high speeds. These burners, which are designed to suit particular applications, have been undergoing trials in industry for some time. Where an ordinary air blast burner has a rate of heat release of some 2,000,000 to 3,000,000 B.Th.U. per cubic foot of flame volume the new design of burner has made it possible to increase this rate up to some 250,000,000 B.Th.U. within a special refractory tunnel or chamber. Combustion is completed very rapidly in the chamber from which the resultant gases are discharged through a narrow opening at supersonic velocities. Air is fed into a burner chamber at about 5 lb per square inch, where it mixes with gas supplied at a pressure of some 2¼ lb per square inch. In developing the burners one of the two particular problems which were encountered was the noise set up by the gases passing through a relatively narrow slot at supersonic velocities; this has been overcome to some extent, although the burners are still far from quiet when in service. The second problem was the development of a refractory material for the body, which would not distort or disintegrate when heated up to about 1700 deg. Cent. in half a minute by a high-velocity flame.

One of the burners demonstrated was of cylindrical construction with a two-piece refractory body in which combustion takes place and the high-velocity gases are discharged through a slot round the circumference. A gas/air supply valve, of special design, incorporated in the body ensures that the high-pressure supply of fuel is distributed evenly throughout the combustion chamber. This type of burner is being made in two or three sizes and is used for the preheating of the interior of cast steel valve bodies prior to the deposition of a hard metal facing. In one particular case a burner enables the required area in a 2-ton valve body to be heated to 750 deg. Cent. in twelve minutes, as compared with six hours previously required. Furthermore, as the heated area can be restricted to just that required with a jet burner, the need for encasing a valve body in a refractory structure to prevent heat losses has been eliminated.

Another form of burner comprises a rectangular mixing and combustion chamber with a discharge grill on one side leading into a slotted refractory body, through the long narrow orifice of which the high-temperature, high-pressure products of combustion are discharged on to the work. An interesting application of this design of burner was demonstrated in a visit to the works of Clayton, Son and Co., Ltd., Pepper Road Works, Hunslet, Leeds, 10.

This is one of the few firms in this country which specialises in the manufacture of large steel tubes by the water gas roller welding or lapwelding method, which is specified for certain applications. By this process a tube of formed steel plate has lapped edges which are heated and then welded or forged together by reciprocation under heavy loading between an anvil and a roller. The machine used was developed originally in 1906 by the founder of the company. It consists essentially of a support beam over which the pipe is placed with one of its ends coupled to a hydraulic-jack-operated reciprocating gear. A gas burner is supported by a cantilever beam which extends part way along the machine over and in line with the pipe beam, and registers over a similar burner on the pipe beam itself. These two burners, each about 18in long, serve heat to the lapped area from both inside and outside the pipe. An anvil is fitted on the pipe support beam a short distance beyond the inner burner, and is in line with a roller on a hydraulic ram fitted on the cantilever beam above. At the end of the predetermined heating period the burners are retracted, and the heated length of pipe reciprocated on the anvil whilst a welding pressure is imposed on the lapped joint by the rollers.

Up till the recent introduction of the new jet burners using town gas, the water gas used for this heating process was made on site, but owing to the intermittent nature of the process and the high cost of coke it was becoming steadily less economic. The new burners, it was stated, have not only proved more economical in service in that the amount of gas used is halved and the welding time reduced by about 26 per cent, but they also give a cleaner and more satisfactory weld. In a particular application demonstrated a 33in diameter pipe made up of ⅜in plate with a ½in lap was being roller welded at a speed of about 15ft per hour, using a roller forging pressure of 12 tons and heating the area of the lap to 1700 deg. Cent. To attain this temperature the water-cooled burners in use were supplied with gas at 1½ lb per square inch and air at 3 lb per square inch.

Another large gas-fired installation in this works is an annealing and stress relieving furnace for vessels up to 6ft diameter and 28ft long, supplied by Dowson and Mason, Ltd. This furnace is fired with twelve tangential jets on each side and is designed for temperatures up to 950 deg. Cent. In the course of a demonstration it was shown how, by its arrangement of jets and system of control, a 62in diameter tube, 18ft long in ⅜in steel, could be raised to 650 deg. Cent. from cold in about twenty-five minutes.

A visit was also paid to the Yorkshire Copper Works, Ltd., where gas is used extensively in tube manufacture. The equipment shown included furnaces, in which copper and alloy billets up to 12in diameter and weighing 4 cwt to 5 cwt are heated prior to extrusion, and fully automatic gas-fired annealing and heating furnaces in the tube production lines.

Johansson Factory Extension

HAVING survived some difficult years, the British offshoot of the Swedish firm of C. E. Johansson, has recently been expanding its activities. On Friday, July 5, an extension of the Dunstable factory was officially opened by Mrs. Woxen, wife of the chairman of the Swedish company.

We learn that considerable additions have been made to the plant, and that the range of products has also grown. Floor space at Dunstable has nearly doubled since 1948, having now reached 26,000 square feet. The inspection staff has grown from four in 1948 to seventeen at the present time.

The products of the Dunstable works include ground thread taps, chasers, screw gauges, thread rolling dies, thread milling hobs, and ground lead screws, but the interesting range of Johansson measuring instruments is made only by the Swedish parent company.

Constant Rate Suspension

A SYSTEM of suspension affording a periodicity independent of load has been evolved by the Engineering Components Division, Dunlop Rubber Company, Ltd., and styled "Pneuride." The weight of the vehicle is carried upon flexible bellows units and the air content automatically regulated to give a constant static deflection; since the volume of working fluid remains unchanged, the frequency is invariant. While the rate of the spring is constant with respect to load, this is not true of deflection, and the suspension is highly progressive, due to the increase in effective area as the unit is compressed, and this characteristic is so marked that bellows of the shape illustrated can only be used for suspensions with frequencies corresponding to small deflections—say 70 cycles per minute. Frequencies

Fig. 1—Air bellows unit

as low as this are obtained by using an air tank communicating with the spring unit, and thus reducing the pressure change for a given deflection. To meet the need for much lower periodicities in vehicles with favourable ratios of sprung to unsprung weight, suspension units of a different configuration are envisaged. The transfer of air between tank and bellows effects a measure of damping, but friction is absent from the springing. This is, of course, of particular value for vehicles with low unladen weights, for which such a suspension is most attractive.

The bellows themselves are made, like heavy duty tyres, of rubber and nylon. There is a steel ring in the "waist" of the bellows to prevent the walls blowing outward, and the ends are clamped between metal plates which are lightly loaded and can be pressings. The sizes at present under trial are nominally of 8in, 10in, and 12in overall diameter, and at 100, 90, and 85 lb per square inch are rated at about 1 ton, 2 tons and 3 tons respectively. The actual pressure in the static condition is of course settled by the load; in the case of the 10in unit, 2000 lb corresponds to 42 lb per square inch, and 4000 lb to 77 lb per square inch. Such a bellows weighs only 2 lb 10 oz without ring and end fittings; it works between 3½in and 9½in long. It is possible to use three convolutions in the large sizes, but more are unstable under cyclic loading. The life of a bellows in service appears likely to be indefinitely long, at least at prevailing air pressures.

The bellows is connected to an air tank which may easily be much larger than itself, sizes of 1000 cubic inches being not unusual for lower periodicities; these tanks may be sealed-off parts of the chassis or suspension. The flow of air to and from the suspension unit is controlled by an individual levelling device for each unit. In order to avoid wasting air and overloading the vehicle compressor, it is highly desirable that this unit shall respond only to sustained demands for valve opening, and on a system which levels laterally as well as longitudinally this is an essential to prevent the suspension connecting for roll in one corner and sending the vehicle into the next biassed the wrong way. A time delay is provided in the valve seen in our illustration by coupling the operating lever to a push-rod by means of a hairpin spring. One end of this rod is trapped between two pistons spring-loaded towards a stop that separates them. Movement of either piston by the push-rod is resisted by the need to force the surrounding oil through an adjustable orifice, and therefore a time lag ensues before a given displacement is attained. Since the initial clamping effort of the hairpin spring is large compared to its rate, the amount of travel on the lever has little influence on the delay. When the lever is returned to the static position, the push-rod is pulled away from the piston and, because the rod closes a large hole in the centre of the piston, the latter returns quickly to its stop and is ready to repeat the cycle.

The opposite end of the push-rod passes out of the oil-filled space through a seal and operates two valves, one directly and one by means of a pivoted lever. These valves have a clearance of about 0·010in; this represents the distance the push-rod must move before opening either valve and hence, with the dash-pot characteristic, determines the delay, which may be of the order of 30 seconds. This clearance, magnified about ten times by the linkage, is the tolerance within which the static height is maintained.

Each valve takes the form of a poppet with a rubber face sealing on a circular seat and held closed by the air pressure and a light spring. There is a non-return valve in the one which controls the admission of air from the vehicle reservoir, since at full deflection the pressure may be as high as 200 lb per square inch, while the other exhausts to atmosphere; both incorporate filters. The levelling valve can be seen in the illustration of a trial installation, and it may be noticed that only a very light tie rod connects it to the axle; the end of the arm has a travel greatly in excess of the design range of 30 deg. each way in order to protect it from being strained.

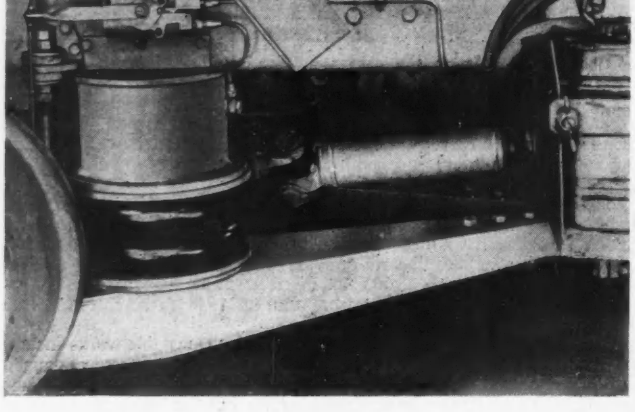


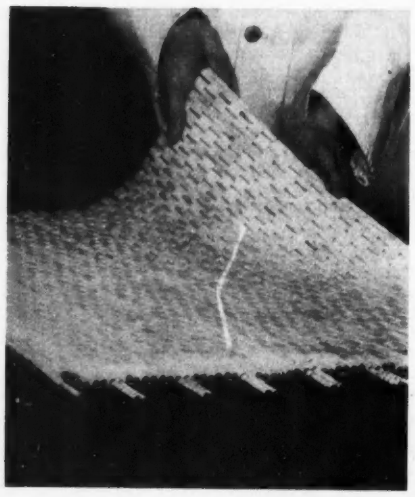
Fig. 2—Air spring fitted to rear suspension

The tank and bellows units, the levelling valves, and connecting piping, all of which may be rigid, comprise the whole "Pneuride" installation on a vehicle with an air pressure system. For vehicles without pneumatics, it is anticipated that the air demand of the suspension will be so low that a replenishable container will be adequate. It is necessary to fit rubber bump stops, and these may conveniently go inside the bellows; it is pointed out that on a vehicle with pneumatic suspension it might be possible to greatly reduce the cost of a suspension failure by deflating the remaining units and driving away on the bump stops. Shock-absorbers will invariably be required when air suspension is used.

The installations that have been effected and designed to date have been for contemporary vehicles with rigid axles, and linkages to locate the axle have had to be added. Since the leaf springs are often not protected from twisting, and therefore add considerably to the roll stiffness, it proves necessary to position the air springs farther outboard, raise the geometric roll centre, or even use the axle as an anti-roll member, in order to gain roll stiffness. In addition to the expected improvements in the suspension characteristics, a lessening of noise is experienced. Compared to a leaf-sprung vehicle, initial cost may be increased, but maintenance expenses are expected to be markedly lower; in view of the damage sustained by bodies due to extremely high suspension frequencies, this might well be true even when automatic lubrication had been used. However, it is clear that the use of such a radically different energy sink should involve a fresh design of chassis, in which case such appendages as Panhard rods would not be invoked.

Flexible Insulated Electrical Heater

WE illustrate one version of an insulated electrical heater element in the form of a flexible mat, designed for a temperature of 1000 deg. Cent., made by Electrothermal Engineering, Ltd., 270, Neville Road, London, E.7. The heater is built up from a network of resistance wires insulated by specially designed interlocking ceramic blocks having high temperature resistance. The general construction of this "flexible furnace" can be seen in the accompanying illustration. The basic unit in this assembly is a ceramic block measuring about

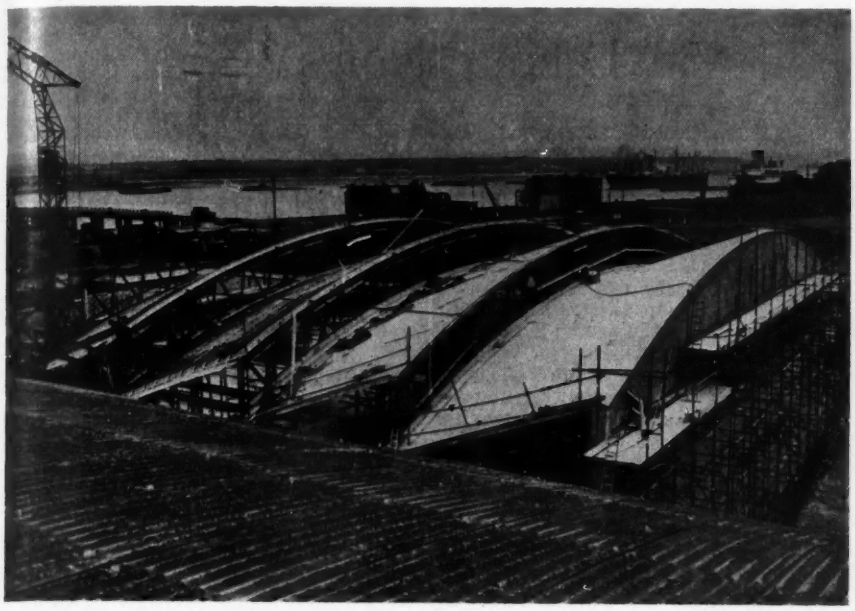


Flexible electrical heater having loading of 50W per sq. in and designed for temperatures up to 1000 deg. Cent. Insulation is provided by interlocking ceramic blocks through which the heating element is threaded

$\frac{1}{16}$in thick by ¾in by ¾in, through which the element is threaded, attaching each block to its neighbours.

The flexibility of this mat in one direction is such that it can, according to the manufacturer, be applied as a heater to parts having a diameter of as little as ¼in. At right angles to the direction of maximum flexibility the mat can be bent to a curvature with a minimum radius of 24in.

The heaters are designed to have a surface loading up to 50W per square inch and controlled temperatures up to 1000 deg. Cent. Rectangular heater units can be supplied in sizes up to 48in square. Larger surface areas can be obtained by linking two or more heater units. The standard range of heaters varies from 3in wide by 12in long, with a loading of 1250W, to 24in wide by 36in long with a loading of 30,000W.



Four bays of the roof structure in course of erection. The concrete shells of two bays are complete, and shuttering is in position for the next two

Composite Steel and Concrete Roofs of Large Span

THE first example in this country of a system of roof construction which has already found considerable application overseas is now being erected at a site at Purfleet, Essex. The roof consists of a series of arched Warren girders of structural steel, spaced about 20ft apart, and connected together by concrete shells between the top chord of one girder and the bottom chord of the next, in the manner shown by the illustration, so that the depth of each girder may be utilised as a north light. The structural capabilities of this system of roofing are a range of spans from 80ft to 210ft, plus an allowable point load of 10 tons suspended from any point of the roof.

The combination of the steel arch and the concrete shell—both orthodox structural forms in themselves—in the particular manner evolved here, has several advantages which will be readily apparent. The Warren girders are of welded mild steel, and are fabricated in the structural firm's works. In the case of the 120ft span at Purfleet, each girder comprised three 40ft sections delivered to the site, and site joints were made between these sections by bolting. The only site welding is in fastening "starter" bars for the shell reinforcement to the tops of the top chords of each girder. The concrete shell is 3in thick and is carried by shuttering supported from the steel arches.

It may be observed that the rise of the steel arch girders is rather shallow, and each arch is tied, between abutments, by a steel tie rod. This tie is also used to prestress the completed assembly. When the concrete has attained 80 per cent of its final strength, the ties are tightened. In the case of the Purfleet roof, the prestressing tension in each tie is 90 tons. Thus it will be seen that the steel girders and the concrete shells have been combined in such a way that a good degree of monolithic behaviour to resist applied loads is achieved. The finished shape is not unattractive from the architect's standpoint, and it is advantageous for drainage and for lighting.

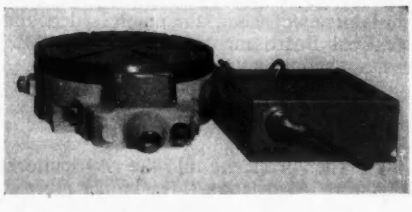
This method of construction is known as the "A.T.A.-Silberkuhl" roof; its designer is Dipl. Ing. Silberkuhl, and it is handled in this country by the A.T.A. Industrial Company, Ltd., in association with a structural engineering firm, Modern Engineering (Bristol), Ltd., which carried out the fabrication and erection of the steelwork of the Purfleet roof. The Purfleet structure is being erected for Thames Board Mills, Ltd., the main contractor on the site being W. and C. French, Ltd.

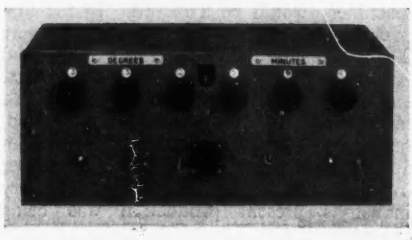
Automatic Positioning Indexing Table

A ROTARY indexing table equipped with an electrical control system which automatically positions the table to selected angles within thirty seconds of arc is now being made by Optical Measuring Tools, Ltd., Maidenhead. The equipment is at present fitted to 16in tables, and where a greater degree of accuracy than that mentioned above is required an optical system can give scale readings direct to two seconds of arc.

The control system was developed by the firm in conjunction with Ecko Electronics, Ltd., and it comprises two units—one mounted on the table and connected by cable to a second unit, which can be positioned where required. The table traverse unit incorporates a drive and a servo head: a ¼ h.p. motor rotates the table at speed to within 1 deg. of the final setting, when a 0·02 h.p. motor takes over for final positioning. Manual control over the motors is provided by means of push buttons for datum shifting.

The table with its traverse unit can be seen in the accompanying illustration with the control unit below. The control unit consists of a rectangular cabinet which has on the front panel six decade switches with adjacent illuminated dials, by means of which the required angle is selected. These six switches represent degrees, minutes, and one decimal place of minutes (0·1 min. or 6 secs.). The other controls on the panel include a start button, a mains switch and an auto/manual switch for use with the push buttons in the traverse unit. Provision for automatic table clamping can be arranged, with a warning lamp to indicate when the clamps are effective.





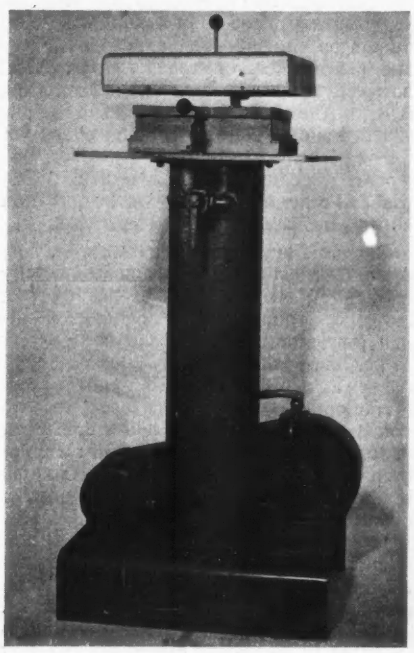
Rotary indexing table with electrical control system which automatically positions the table

The control system contains no electronic valves and consists of a series of Wheatstone bridges, the master potentiometers of which are set up to the desired values. The drive unit turns slave potentiometers until voltages in the bridges are balanced out. The first three digits of an angle are sequentially selected by counters, coupled to the slave potentiometers, which count the number of turns made by the worm shaft. The last three digits are resolved by a slave potentiometer wound over 360 deg. This is set up by three master potentiometers to facilitate decade presentation.

Vacuum Forming Machine

A SMALL vacuum forming machine, for shaping thermo-plastic sheet, which is simple to operate and maintain, is now being made in two capacities by M. L. Shelley and Partners, Ltd., 280, Earls Court Road, London, S.W.5. The straightforward construction of the machine can be seen from the illustration below. It is primarily intended for short-run batch work.

The machine's pressed steel base carries a central tubular column, which is exhausted to provide a vacuum reservoir by a pump driven by belt from a ⅓ h.p. motor. A table on the column carries the mould box, and has openings which are connected through a lever-operated valve below to the vacuum chamber. The heater is supported on a pillar at the rear of the table, and is swung by hand over the plastic sheet on the mould box for the heating cycle. The height of the heater can be adjusted to suit the work. A pedal-operated shaft extending up the column can be used to raise the platen and push the male mould into the plastic sheet when the machine is being used for drape forming. If required, a plug-assisted forming attachment can be provided to push the plastic sheet into a female mould before the vacuum is applied.



Hand-operated vacuum forming machine for thermo-plastic sheet materials

The machine is available with a table assembly to take either 12in by 12in sheets or 18in by 18in sheets. On the smaller capacity machine mould frames from 3in to 4½in deep can be accommodated and on the larger table frames from 3in to 5in deep. The first machine has a 2kW heater and the larger machine one of 3kW.

Industrial and Labour Notes

Economic and Industrial Trends

In the June issue of *Bulletin for Industry*, the Treasury says that, in the first three or four months of this year, economic trends were confused by a number of special factors such as strikes and the late arrival of shipping. But, the *Bulletin* continues, most of this country's main industries are now increasing their production. Coal output is up more than 3 per cent compared with a year ago, and only the declining share of large coal—an inevitable consequence of mechanisation—mars the picture of general improvement. Output of gas, gas coke and electricity in the early months of this year was lower than in the corresponding period of 1956, but that was on account of the mild weather. Steel plants increased their output by 4 per cent in the first five months of the year, and the output of chemicals is now rising again.

The *Bulletin* adds that investment demand is probably still increasing, though at a rather slower rate. Estimates from manufacturing industry indicate that investment expenditure in the first quarter of this year was a tenth higher than a year earlier. It was a rather smaller rate of increase than in recent years and was made up of a quarter more on building, a tenth more on plant and machinery and a tenth less on vehicles. Elsewhere, however, there may have been "offsetting falls." Allowing for changes in cost, it is stated, building work in the first quarter of the year, helped by the good weather, was 6 per cent greater than a year earlier. Industrial and other new building work apart from housing increased by about 15 per cent.

Other matters referred to in the *Bulletin* are industrial production and the labour market. It is explained that the index of industrial production was no higher in the first four months than it had been a year earlier, but in the seasonally adjusted figures there was a distinct upward trend in those four months. By April the index was two points, or about 1½ per cent, higher than it was in January. In the labour market, there has been little change so far this year. The fall in unemployment and the rise in the number of vacancies from mid-March to mid-May were seasonal, and, as in the preceding few months, unemployment was higher than the total of outstanding vacancies. Civil employment was still lower than a year earlier. The *Bulletin* says that there are no figures available as to profits earned in the first five months of this year. The wage rates index in May, however, was nearly 4 per cent higher than at the beginning of January and 5 per cent higher than in May 1956. This takes into account all the recent major wage settlements in engineering and shipbuilding, mining and building. Retail prices were almost the same in May as in January and were 2 per cent higher than a year earlier. But, the *Bulletin* comments, "part at least of the higher incomes which have been generated will work through to prices."

Coal Production

Following an annual custom, the chairman of the National Coal Board, Sir James Bowman, addressed the conference of the National Union of Mineworkers on Thursday of last week. He spoke about the coal mining industry's performance so far this year, commenting that its significance had not been matched in any previous year. At the end of June, Sir James said, deep-mined output, after adjusting for holidays, was 1,900,000 tons higher than in the corresponding period of last year, and opencast production was 707,000 tons greater. Two main factors had contributed to the increase. The first of them was a continuing rise in output per manshift, which had accounted, in round figures, for an extra 1,000,000 tons. The other factor was that there were more men in the industry and more men at the coalface. This latter factor, Sir James explained, was not apparent from the published figures because more accurate methods of recording manpower by place of work had been introduced last year, and adjustments had to be made to the figures to allow for that. The average number of men at the face, he said, was in fact 1600 higher this year than last over the first six months, and that had contributed about 600,000 tons to the total increase in output.

Later in his address, Sir James made further reference to the subject of colliery manpower. Despite the increase, he said, the industry had been and still was short of men. The coalface capacity had been there but it had been impossible to take it up fully. This, he suggested, had resulted in a frustration which had done the industry no good. The period of the year during which the greatest increase in manpower might be expected, Sir James remarked, was now over, and already there had been some seasonal decline. But even so, the latest figures showed a gain so far this year of 6900 men compared with 3000 in the corresponding period of last year. Nevertheless, Sir James added, the strength of mining manpower was not what it ought to be; 9000 to 10,000 more men were needed. From that, he went on to say that there was a third important factor which must be considered in assessing the coal mining industry's performance, namely, attendance. Last year, Sir James stated, nearly 1,000,000 tons more was lost through increased absence than in 1955. That was far more than the losses through falling manpower, and, in fact, completely wiped out the hard won gains from increased productivity. In the first ten weeks of this year, he went on, an improvement in attendance contributed materially to the industry's performance. Since then, however, that advantage had been almost lost. With the new bonus provisions, Sir James emphasised, the union leaders and the Coal Board must take care that "the position should not worsen."

Agricultural Machinery Exports

The president of the Agricultural Engineers' Association, Mr. Lionel Harper, said last week that there were now indications that this year's exports of agricultural machinery would be a record. In the first five months of this year, export sales were 20 per cent in advance of 1956. Substantial orders had been received from Yugoslavia, and sales to France, Finland and Iraq had increased. Furthermore, Mr. Harper added, business in the dollar areas was showing an appreciable increase. Altogether, he stated, over 60 per cent of the agricultural machinery industry's present production was being exported.

At home, Mr. Harper continued, there was an improvement in machinery sales, compared with last year. Farmers were certainly becoming more selective in their purchases and some machines were "slow moving" as far as sales were concerned. But the sale of others, particularly tractors, combine harvesters, balers and silage making machinery, was ahead of last year.

Technical and Commercial Education

The annual conference of the British Association for Commercial and Industrial Education was held in London last week. It was opened on Wednesday by the Minister of Education, Lord Hailsham, who spoke about this country's over-riding need to "keep ahead" in order to maintain economic prosperity. The increasing industrialisation of the less developed countries was inevitable, Lord Hailsham said, and in the wider context healthy. This country's products were bound all the time to become more complex and to depend more and more on science and technology rather than on the empirical skill of the craftsman. We could maintain our place in the world only if we deliberately set out to develop to the full all the talent in the nation.

Lord Hailsham went on to talk about the need to take care of industry's manpower needs. That, he remarked, was a new problem. During the next five years, Lord Hailsham continued, industry would be presented with a "once and for all opportunity" to do itself and the nation a service which could be achieved by no other means. There were few major industries which had not now adopted national training schemes, but the implementation of those schemes, in many areas, still had to be worked out with the technical colleges. In certain fields, Lord Hailsham observed, and in commerce particularly, the development of part-time day release had only just begun. Co-operation between industry and the technical colleges, he urged, was most important. These colleges were peculiarly industry's affair; experience had already shown the great benefits which could be derived from a mixture of industrial and academic training. Lord Hailsham expressed his belief that there were large numbers of people in this country who could derive more benefit from that kind of education than from a purely theoretical course.

Selling to Industry

The British Institute of Management has published a report entitled *Selling to Industry*, which presents the findings of a study group of which Mr. Hugh Weeks was the chairman. The study group included representatives of structural engineering firms, boiler makers, electrical engineering, mechanical handling equipment manufacturers, steel and chemical works, and printing machinery makers.

The report suggests, among many other matters, that "the search for new uses of a company's products may be one of the more important functions of a marketing executive selling industrial goods." In view of the need for accuracy in planning industrial sales, the group urges that more emphasis should be put upon the marketing division as "an intelligence centre where information from all sources is collected, analysed and translated into programmes."

The Zuider Zee Reclamation

(No. II—*Concluded from page 999, June 28.*)

The Eastern Flevoland polder—the third large polder to be reclaimed from the Ijsselmeer—is now almost completely drained, and crops have been planted in some areas which are already dry. In the first part of this article, published in THE ENGINEER *of June 28, we described the whole scheme of reclamation for the Zuider Zee; here we give details of the work now in hand at Eastern Flevoland. The polder is 128,000 acres in extent, with a perimeter dyke 56 miles long. The "reclamation" works include preliminary cultivation; it is expected that the last farms will be let for normal use in about ten years time.*

RECLAMATION in the Ijssel lake is eventually to be carried out to the extent of 541,000 acres, an area equal to about 7 per cent of the total land area of Holland, but equal to about 10 per cent—and this latter percentage is particularly stressed by the Dutch—of that country's total agricultural acreage. The areas involved are shown on Fig. 6. The Wieringermeer, as we noted last week, was reclaimed at the time the main dyke was constructed and was under cultivation in 1933. It was flooded by the Germans in 1945, and extensive reconstruction was needed to restore it. The north-eastern polder was drained during the war period, but work on it was delayed by the war; the first houses were built in 1943. Now it is fully productive, and its population, twelve months ago, was over 23,000.

For various reasons the southern polders are considered as a unit from the planning point of view. Their total size was fixed from the criterion that the minimum ultimate area of the Ijsselmeer should not be less than 309,000 acres, leaving about 370,000 acres available for reclamation in the southern group. The area south of a line Enkhuizen-Kampen was the obvious choice for this reclamation; north of this line, the Ijsselmeer is deeper, and furthermore it has a sandy bed which would give only a poor soil if reclaimed. A start was in fact made on the Markerwaard polder before the war, and a length of dyke north of Marken island was built. Since then, the plans have been recast, and Markerwaard will now be constructed following completion of the Eastern Flevoland works.

One of the first considerations in planning these polders was that of retaining existing ground water conditions in the lands bordering on them, where these conditions were important for agriculture or for other reasons. It was decided that a large lake would be necessary in the area close to Amsterdam. Some earlier schemes envisaged draining the whole south western area. Amsterdam, however, cannot tolerate any lowering of its water table, since most of the buildings are carried on timber piles, which would rot if they dried out. The present scheme, therefore, envisages a lake, about 7 miles across, the Ijmeer, in the region close to Amsterdam. It will be separated from the enclosed Ij waterway of Amsterdam and the North Sea Canal, and will be kept at a level of −0·5m N.A.P. This will be sufficient to discharge water through Amsterdam's canals and through the North Sea Canal, to offset the entry of salt water through the locks at Ijmuiden. The lake will also have "recreational" uses, and will be large enough to receive, and finally purify, Amsterdam's sewage.

The Ijmeer will join with the nearest boundary lakes of the polders—the Gouwmeer, which will be between the Markerwaard polder and the mainland, and the Gooimeer, which will separate the South Flevoland polder from the old land. The arrangement of these lakes is shown in the plan, and the Veluwemeer, the principal lake serving the Eastern Flevoland polder in this way, may be noted. The lakes are divided at intervals, so that they will be kept at appropriate levels to suit the adjoining land, and they will be used for navigation, the various locks being indicated on the map. Generally, the southern lakes have a bed of sand, into which the hinterland drains, and which would therefore have induced excessive draining if reclaimed, as far as agriculture on the old land was concerned.

In dividing up the southern area into polders, one large area was considered too cumbersome and there is modification to Lely's original plan here; his proposal for a large southern polder has been changed to the extent that this polder will be built in two stages. Another principal decision was to build a large canal between the southern and Markerwaard areas. Economically, this canal will be important in the development of the polders, since it will join Amsterdam directly with Lelystad, the principal polder town. But it has other advantages too. Pumping stations can be built alongside it, hence giving better drainage arrangements in the polders. Water drained from these areas will also have a comparatively high salt content, we understand, so it will be advantageous for it to be evacuated through the North Sea Canal. The canal will be ¼ mile wide and will have an open connection with the Ijmeer, with locks at Lelystad, where it will connect with the Ijsselmeer.

An economic study of the Flevoland polder plan indicated that division into an eastern and a southern section would be advantageous. By building the dividing dyke and hence draining Eastern Flevoland and getting it under cultivation some years sooner, the capital cost of the dyke is apparently more than offset. It was also considered that the Eastern Flevoland should be built before the other two polders so that the development of Lelystad would proceed more quickly. It should be borne in mind that the rate of progress of the scheme depends to some extent on the general economic state of the country, and a unit of the size of Eastern Flevoland is more advantageous.

The Eastern Flevoland Polder

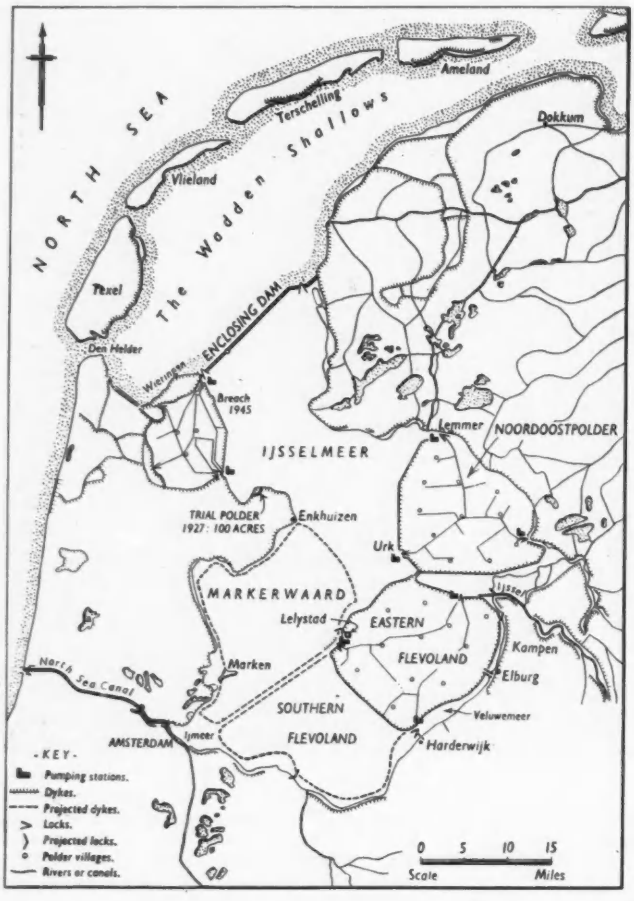
Having now pointed out some of the principal factors determining the planning of the polders, the layout of the Eastern Flevoland polder itself may be described in more detail, with emphasis on the civil engineering problems of its construction. The work here has, again, been typical of Dutch civil engineering.

The undrained polder land lay at a level of about 2m below the Dutch mean sea level datum (N.A.P.) along its southern boundary, and gradually sloped downwards to the north, to a level of about 4m below the datum. The canal system which will drain the polder has been divided, provisionally, into two sections at levels of −5·2m and −6·2m N.A.P. respectively. Other leading figures for the Eastern Flevoland polder are listed in the table.

The illustration at the head of this article shows a typical length of completed dyke, before drainage of the polder was started. The reclaimed area will be to the right of the dyke in this illustration. This particular length is on the western perimeter of the polder, about 12km from Hardewijk (a town on the old coastline, at the south-western corner of the polder). The enlarged section of dyke was originally a harbour during the period that constructional work on the dyke in this area was in progress; when work was complete the harbour was filled in.

A typical sequence of operations in dyke building will give an idea of the importance of floating plant for this work, and the advantage of having a tideless, comparatively calm lake to work in. Reference to the cross-sectional drawing, Fig. 7, shows the finished dimensions of the dyke.

The first operation, which was necessary in areas where the top layers of the lake bed were soft, consisted of removing a depth of about 6·5m by dredging; the trapezoidal section of this excavation below the original bed level shows its extent, which, of course, was determined by normal soil mechanics analyses. Then sand was dredged from the nearest convenient area, transported by bottom-dumping barges, and dumped into the dredged trench. This process continued, above the



	Acres
Area of Ijsselmeer after completion of reclamation...	309,000
Areas reclaimed :	
Wieringermeer polder	50,000
North-East polder (Nordoostpolder)	118,500
Eastern Flevoland polder (Oosterpolder)	128,000
Areas to be reclaimed :	
Markerwaard polder (Westerpolder)	134,500
Southern Flevoland polder (Zuiderpolder)	110,000
Total	541,000

Fig. 6—Reclamation scheme for the Ijsselmeer. Work is now in progress on the Eastern Flevoland polder

original lake bottom, up to the minimum depth in which the barges could operate.

On each side of the shallow, wide bank of sand thus formed boulder clay was then placed, to form two embankments, extending above water level. The boulder clay was brought by barge and placed by floating grab cranes, a more substantial bank being placed on the outer edge. The slopes of these clay banks were then protected by driving sheet piling—generally timber sheet piling—at about water level, and by sinking willow mattresses on the slopes, by loading them with stone. The stone on the inner slope will be used again later, when the polder is reclaimed, but its size is great enough to have made protection of the inner slope necessary at this stage.

The two clay banks completed at this stage then acted as bunds for the next operation, namely, that of completing the remainder of the main mass of the embankment by the hydraulic emplacement of more sand. When the central core of sand had been built up to the highest level practicable by this hydraulic method of placing, further shaping, to the required cross section, was carried out by excavating plant working on the dyke. A revetment of boulder clay was added at this stage, above each of the banks already placed. The exposed clay faces were protected by stone pitching, the stone being laid on mattress work of straw and timber faggoting. Finally, the entire sand core was protected by an outer covering of weather-resistant materials, as the cross section shows.

The dyke building is remarkable for its economy, since only the basalt used for underwater pitching is brought from any great distance. This leanness of design is essential when the work is on such a great scale, 56 miles of embankment being needed for this one polder. The photographs reproduced with this article show several stages of the dyke building, and the main kinds of floating plant for operations such as placing boulder clay and hydraulic fill can be picked out from them. At certain strategic points enlarged dykes were built, principally to form storage or working areas (since the dyke was raised from the lake bed many miles from the shore), but also as part of the final scheme, as explained below. This construction follows established Dutch practice. One experiment was tried in replacing the willow mattress by a flexible mattress of asphalt, which could be sunk in position by a special craft. After some trial work, however, the traditional willow mattress was reverted to, as the most satisfactory method.

Pumping Stations

Construction of the three pumping stations proceeded simultaneously with dyke building. This was essential, so that as soon as the dyke was closed pumping could be started. The task of pumping out the polder, once its enclosure was completed, is one covering a period approaching a year, so obviously the pumps must be put to work as soon as possible.

At each of the three pumping station sites the embankment was divided to form a large cofferdam, which was then dried out for the construction of the pumping station substructure. A good idea of this work is given by the last illustration, which shows the Wortman pumping station being constructed inside its cofferdam. Although these works were again on a large scale, they have followed generally accepted practice in their design and construction.

We also show the Wortman pumping station in cross section. The other two pumping stations—Lovink, near Hardewijk and Colijn on the eastern side—are generally similar but both are electrically powered from the grid, and there are only two pumps at the Colijn station, as against three at Lovink and three at Wortman. The provision of one diesel-powered station is helpful for peak load tariffs, added to which the Wortman station will be beyond the practical range of high-tension transmission until the reclamation is well advanced.

In earlier schemes of this kind the pumps have been designed for changing their rotors, for in the early stages of pumping out a polder the head against which they work is very low and only in the later stages are the heads of the same order as the pumps will experience for the rest of their working lives. In this case, however—the entire range of heads is about 0 to 6m—the large centrifugal machines installed have a head range covering both contingencies. The electric motors at Lovink and Colijn are of 900 h.p. and drive their respective pumps directly. The diesel engines at Wortman are 1000 h.p. machines at 225 r.p.m., and they drive through bevel reduction gearing. They can be governed over a range of 150 to 260 r.p.m. There is provision for the installation of a fourth diesel-driven pump at Wortman, which will be needed when the Southern Flevoland polder is reclaimed. The station also includes two diesel-powered generating sets for supplying electrical power to the Lelystad dyke settlement.

The pumps at all three stations have a capacity of 500 cubic metres per minute against a head of 6m when operating at 110 r.p.m. The runner diameter is 2340mm and is an eight-bladed design evolved after model research to suit the range of heads experienced.

The problem of calculating the required pumping capacity for ensuring safety from floods has apparently been tackled in a manner very similar to the flood computations used in this country. The " time of concentration " for a polder of this size is quite long, and the three pumping stations are able to deal with a severe rainstorm with only very slight increases in the water levels in the canals.

Statistics for the Eastern Flevoland Polder

Total length of enclosing dykes	56 miles
Number of pumping stations serving the polder	Three
Total number of pumps installed...	Eight
Capacity of each pump	110,000 g.p.m.
Nominal size of ships using locks :	
(*a*) Main lock on Amsterdam/Ijsselmeer canal	2000 tons
(*b*) Lock giving access to the polder at Lelystad	600 tons
(*c*) Lock giving access to polder at Colijn, and Veluwemeer locks	250/300 tons
Maximum width of the Veluwemeer...	2200 yards
Soil classification of the polder :	
Clay and heavy clay	74 per cent
Heavy sandy clay	14 per cent
Light sandy clay	8 per cent
Sand	4 per cent
Levels of canals in the polder	—5·2m N.A.P. and —6·2m N.A.P.
Unit size of farms in the polder	1250 acres

Layout of the Polder

Several features in the layout of the Eastern Flevoland polder had an important bearing on the way it was constructed, principally the works in the neighbourhood of the future town of Lelystad.

Eventually, the town will be situated at the end of the Amsterdam/Ijsselmeer canal, and, being the capital town of the polder regions, rather more elaborate planning is involved here. The polder dyke bends round the end of the canal (as shown on the map), and an area inside the polder cutting the line of the canal is to be raised to a higher level by pumping in sand fill. The town centre and the main public buildings of Lelystad will be built in this area. They will thus command

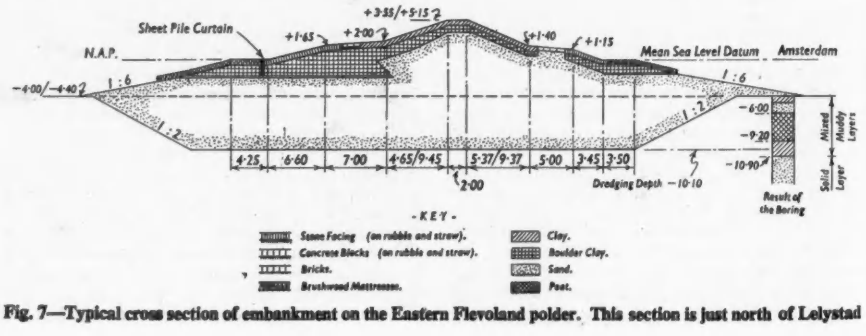


Fig. 7—Typical cross section of embankment on the Eastern Flevoland polder. This section is just north of Lelystad

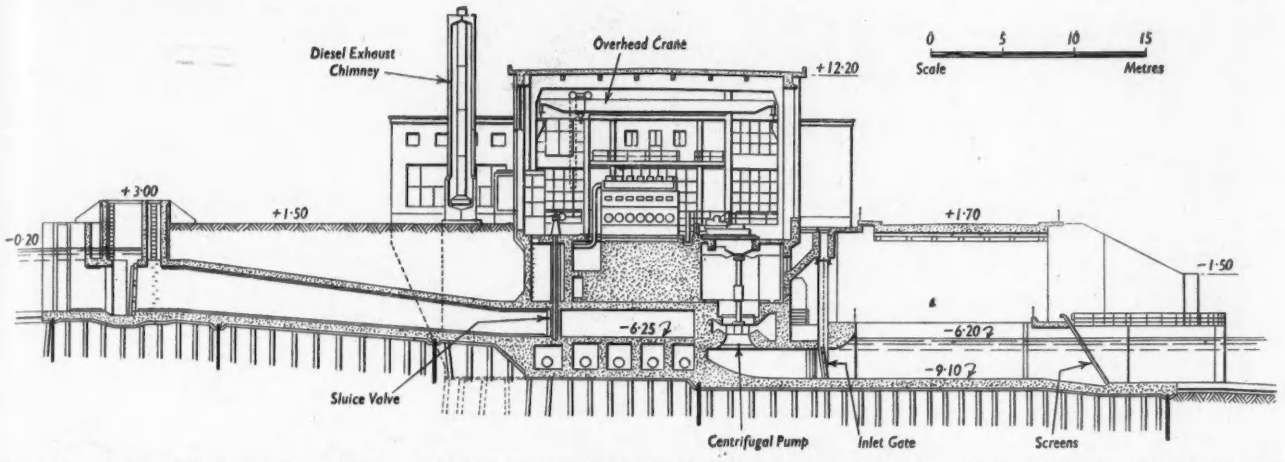


Fig. 8—Cross section of Wortman pumping station at Lelystad. Three pumping stations drain the Eastern Flevoland polder. Wortman is diesel-engine-driven, the other two take power from the grid.

a fine view of the surrounding polder lands, and, in particular, a view along the main canal. They will also be the main visual attraction looking along the canal from the other direction.

The polder dyke in the area of Lelystad—that is to say on both sides of the Wortman pumping station—has been a centre of activity during the constructional period. Houses and other buildings have been built on the dyke, and further on, there are areas for storing the materials used for dyke building. Opposite this length of dyke, along what will be the northern bank of the future canal, a length of dyke eventually to be incorporated in the perimeter of the Markerwaard polder has been built. This dyke can be seen in the background of the last illustration. Several breakwaters have been built across between the two dykes, to give sheltered harbours for craft at work in this area. For building the large locks at the end of the Amsterdam/Ijsselmeer canal, a cofferdam, somewhat similar to the Wortman cofferdam illustrated, but much larger, will be needed. Work on the embankments of this cofferdam—which is itself a major civil engineering task—has already begun.

At the south-western corner of the polder, by the Lovink pumping station, a widened area of dyke and a constructional harbour were also built. At this point, the embankment has been built out from the shore of the old land at Hardewijk and it joins the south-western corner of the polder about 2 kilometres from the old shore line. To the east of this length of dyke —between the old and the new land—lies the lake known as the Veluwemeer. A lock, adjacent to the Lovink pumping station, gives access to the Veluwemeer from the west. Before construction of the south-western polder, and before the Lelystad locks are closed, this lock will be permanently open. To protect it from westerly weather, which would cause a "piling up" of water through it, a breakwater dyke has been built, to the west of the access dyke to the polder, and extending from the shore as far as about a kilometre beyond the lock, where it ends quite close to the polder dyke. The area between the two is used as a harbour.

The length of polder dyke bordering on the Veluwemeer has been built with an eye to "recreational" uses. Islands will be left, here and there, and very wide dykes have been built for afforestation of a lake-side strip of land, and also for forming sandy beaches, and areas for wild fowl, and pasturage, bordering on the lake.

Roads and Canals

The crest of the polder dyke is of course the first road communication to be brought into use. Access to this road is at present gained at Hardewijk, and also at Roggebotsluis where a lock will serve the opposite end of the Veluwemeer (the lock is marked on the map). Eventually it is planned to have a motor road from Amsterdam to Lelystad, along the Markerwaard polder, then passing across the Eastern Flevoland polder to its north-eastern tip where a bridge will be built across to the north-eastern polder, thus giving an important trunk route. A bridge is also to be built across the Veluwemeer at Elburg.

Canal routes have already been described, since the main canals serve both for navigation and drainage, and the principal canals in the polder are shown on the map. The increasing simplicity of the canal systems of the later polders is one of the economies which experience has brought about in this class of work; it will be seen that the Wieringermeer polder canals are the most elaborate.

The locks of the Eastern Flevoland system are all built in reinforced concrete along conventional lines, but are noteworthy for an arrangement of sluices which introduces the water filling the lock without turbulence. The polder lock at Lelystad is 213ft by 28ft by 10ft, and the other locks are 148ft by 22ft by 8·5ft in size.

Excavation of the polder canals is carried out by dredgers before the polder is drained. The dredgers work across the bed of the polder, during the period when it is being pumped out. So the principal excavation is all carried out before the land is dry.

Other Aspects of Reclamation

The civil engineering works involved in reclaiming an area such as the Eastern Flevoland polder, although vast and complicated are only a part of the total effort which must be brought to bear before the new land is an integral part of the community. The organisation of the Zuider Zee scheme naturally covers all these other aspects, and here the scope of the problem brings to mind the approach made so familiar by the Tennessee Valley Authority. At the stage when the land is drained the problems are still technical, covering drainage, crop planting, and building roads and houses. But social and economic planning is also necessary. A few words may be said about both these topics.

The land can be cropped immediately it is dry, but in the first years there are special hazards to be faced, so this stage of the work is still under government control. The various sections of Eastern Flevoland will be brought into cultivation successively over an eight-year period. Some areas are already under cultivation, notably along the southern edge, which dried out this spring some months earlier than the more low lying land to the north. In other areas, totalling 30,000 hectares, reeds are being encouraged by sowing seed from aircraft. Reeds are far easier to deal with than other weeds later on when the land is to be cultivated, and hence it pays to carry out this sowing programme.

The amount of subsidiary drainage—agricultural drains and the like—needed in the polder is enormous. This work goes ahead as quickly as possible, trenches being excavated through areas already planted. Special measures against seepage are needed in the early days of reclamation and the level of the land is expected to sink about 80cm or 100cm due to shrinkage.

Eventually, when roads and houses and farm buildings have been completed, the farms will be let. The standard size of the farm plots is to be 1000m by 300m. Courses for training farm labourers in mechanisation will be held.

In the early years before letting, the crop rotation will be colza, wheat and flax, or alternatively wheat, barley and lucerne. In the last years a tile drainage system will be introduced, and drainage furrows filled in. This work will be completed by 1964, and it is expected that the last leases will be granted by about 1967.

Fig. 9—Typical sequence of dyke building operations. In the background boulder clay is being placed by floating crane, and in the foreground hydraulic emplacement of sand is in progress

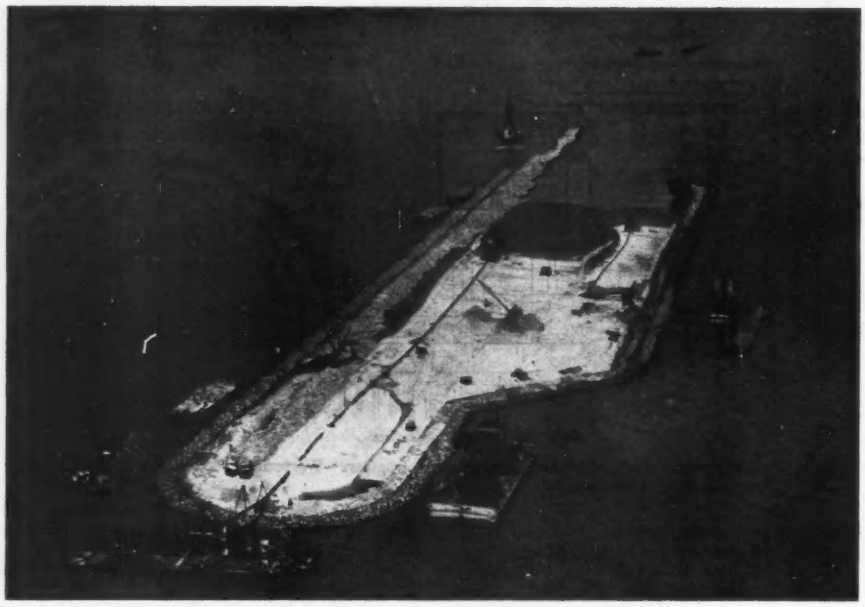


Fig. 10—Construction of a widened section of the Eastern Flevoland enclosing dyke is shown in progress. Floating plant is again typical of this work

It is anticipated that Lelystad, in contrast to the almost purely agricultural nature of most of the polder lands, will have a certain amount of industry, The town's population is expected to be about 30,000, with the possibility of double that number if local industries become established. As the Zuider Zee scheme progresses, it is thought that the polders may be formed into a new province, of which Lelystad would be the capital.

There will be another town of 3000 to 5000 inhabitants in the Eastern Flevoland polder, and, in addition, nine or ten villages. If these centres follow the general style of the neighbouring north-eastern polder, the whole area will be laid out with orderliness and precision, in which the rectangular 1000m by 300m plots predominate, almost with the regularity of an architect's "module."

The works following the civil engineering—in particular buildings—account for a large part of the cost. It is necessary, for instance, to have churches of three denominations in each village. But again, if the same general style is maintained as in the north-eastern polder, it can be expected that a most pleasant and attractive region will be created. The largest town of the north-east polder—Emmeloord—is much smaller than Lelystad will be, but it is nevertheless a good example of modern town design and architecture. Lelystad will, in fact, be an entirely novel venture in reclamation, and we await with greatest interest the emergence in a few years time of this comparatively important town, with its harbour and locks, its industry, and its architectural prominence over the polder lands.

Dates for the estimated completion of the agricultural "reclamation" in Eastern Flevoland have been given above. Otherwise, reclamation in the Ijsselmeer depends on general economic conditions, and possibly other factors, too. In 1953, for example, the plant in use for dyke building was taken over for emergency repairs in Schouwen-Duiveland in south-western Holland (see THE ENGINEER's supplement on Dutch engineering works, June 11, 1954) after the disaster of that year. At present, however, it is hoped that the whole scheme as described in these two articles will be finished by about 1980.

Constructional works for sea defences, canals and roads are, in Holland, the responsibility of a governmental body—the Rijkwaterstaat. The planning and execution of the civil engineering works we have described are the responsibility of a department of the Rijkwaterstaat, namely the Zuiderzeewerken. There is also a Zuider Zee polders authority, which is responsible for the building works within the polder, letting the farms and so on.

The Dutch contracting firms which carried out the building of the 56 miles of dykes at Eastern Flevoland were : N. V. Maatschappij tot Uitvoering van Zuiderzeewerken ; Keteldiep door het Aannemersbedrijf v/h J. P. Broekhoven N.V.; and Zuiderzeecombinatie v.d. Hoeven-Zanen. Mechanical and hydraulic plant for the three pumping stations was supplied by Machinefabriek Gebr. Stork and Co. N.V., and electric motors by N.V. Heemaf (Colijn) and N.V. Elektro-technische Industrie v/h Willem Smit (Lovink).

The cost of hydraulic works for the Eastern Flevoland polder has been estimated at nearly 290 million guilders, and the "cultivation of the soil," nearly 350 million guilders.

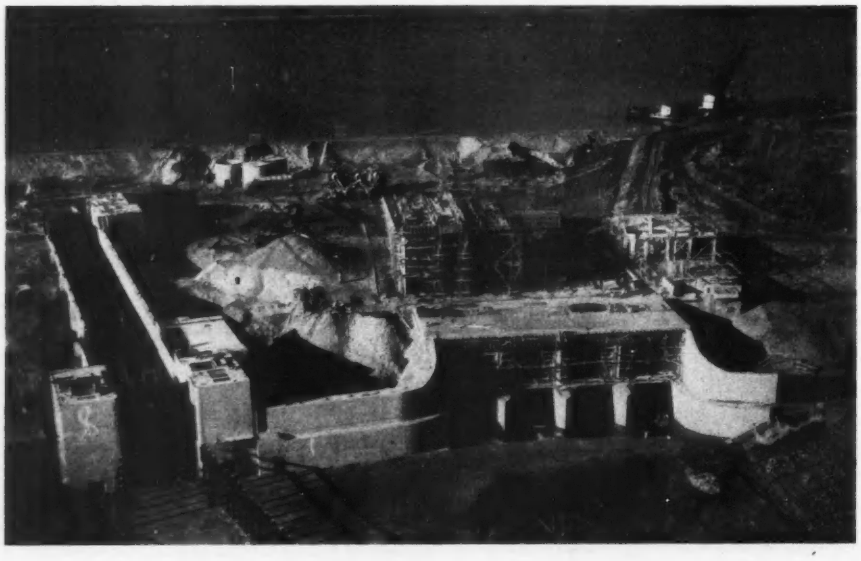


Fig. 11—Wortman pumping station and the lock giving access to the polder are shown under construction inside the cover of a large cofferdam

International Atomic Exhibition at Amsterdam

On June 28 the exhibition "Het Atoom" opened at Schiphol Airport, Amsterdam ; it is to continue until September 15. The exhibition has much to offer to the interested layman as well as to the non-specialist technician, depicting modern atomic science as an important facet of the present stage of the social and cultural development of mankind. While the atomic power aspect naturally predominates, the educational value of the exhibition lies to a great extent in its illustrating the historical origins of the energy problem as well as of modern atomic physics, together with the most important side connections to other branches of science and technology.

From models of machines known already to the ancients which relied on human or animal muscular effort, the visitor proceeds to exhibits showing the utilisation of fossil fuels since the advent of the steam engine. The question of alternatives to the waning coal and oil resources of the world is broached by references to water, wind, solar, and tidal power. The non-technical visitor in particular will welcome the next section, which deals with the evolution of the concepts of atomic science from the days of the Greeks and continues with diagrams and models illustrating the structure and properties of crystals, molecules and atoms. This is followed up by a description of the discovery of radio-activity, and the development of this branch of physics up to the discovery of nuclear fission and of the chain reaction. Many fundamental phenomena are demonstrated by means of apparatus identical with or similar to actual equipment used in the laboratory ; a fact which will be especially welcome to those for whom Geiger counters and Wilson cloud chambers have until now been mere words from the scientific column of their newspaper. How it is possible to influence the phenomena of the infinitely small is shown by examples of large particle acclerators which are on view together with some of the high-voltage gear required ; and one consequence of the law of the equivalence of mass and energy is shown by a small quantity of uranium and the enormous equivalent block of coal. One of the major items on view is a swimming pool reactor in full operation, charged with 15 kg of 20 per cent enriched uranium. The principle of the chain reaction, moderators and control rods are explained by means of demonstration apparatus, while models of graphite and other types of reactor illustrate the manner in which nuclear fission is being put to practical use. A further large section of the exhibition deals with isotopes and their applications in medicine and biology, as well as in engineering. The subject matter of the "Het Atoom" exhibition is further detailed in the films which are to be seen in the exhibition cinema. The adventurous spirit of science (fiction and fact) is the theme of two "side shows," "The Visions of Jules Verne" and "The History of Aviation in a Lifetime."

The American Scene

BY OUR AMERICAN EDITOR

Centenary of the American Steel Industry

The celebration of the centenary of the American steel industry has been in progress for more than a year and will continue for the next few months as holiday-makers visit various places of interest around the country that have important associations with America's colourful history in the iron and steel-making field. In February, 1956, the Metals Branch of the American Institute of Mining and Metallurgical Engineers held one of the first sessions devoted to the origins of Bessemer steel and the introduction of the process in this country a century ago. Because the story is a long one and so full of well-known incidents and of obscure and forgotten episodes, extending over a period much longer than a century, confusion may arise as to just what the present celebration is and is not commemorating. Agricola, in his *De re metallica*, published in 1556, described a method for making iron into steel; it was this same method, further elaborated by Reaumur in France in the early eighteenth century, that was used by American founders before the Revolution. So 1957 is certainly not the centenary of the discovery of steel, in America or anywhere else. The first iron works built in America was at Falling Creek, Virginia, some fifteen or twenty years after the landing at Jamestown in 1607, but when it began to belch forth flame and smoke, the Indian Chief Opechancanough saw in it premonitions of a world hostile to the Stone Age culture of his people, so his braves destroyed it utterly and massacred 347 of the 348 colonists. To-day, the most notable restoration of an early American iron works is that at Saugus, Massachusetts, where a mid-seventeenth-century plant can be studied in every detail. Steel entered the picture in American engineering at Simsbury, Connecticut, about 1725, when small quantities of high-quality steel were made for sword blades and cutting tools, using the method then common in England of packing forged iron bars in a furnace with charcoal and charcoal dust and keeping the mass at a cherry red heat for many days. By 1793, when Tench Coxe wrote his *View of the United States*, he stated that half of the steel consumed in the country was "home-made." Hence this year 1957 is something other than the centennial year for the first making of steel in the nation that is now the world's greatest source of supply. Many things happened in 1857 to make that year significant in American industrial history as one looks back to-day. John Fritz patented the first three-high rolling mill, although Abram Hewitt had used the idea two years earlier without taking a patent on it. In the same year, E. B. Ward built Chicago's first rolling mill where, eight years later, the first steel rails in America were processed experimentally. In Worcester, Massachusetts, Ichabod Washburn found new methods for hardening steel wire, and in the Lake Superior region the first railway for carrying ore to a lake port was built. But it is the registration of a patent to William Kelly, of Kentucky, for a pneumatic converter on June 23, that fixes 1857 as the birth of the Age of Steel in the United States.

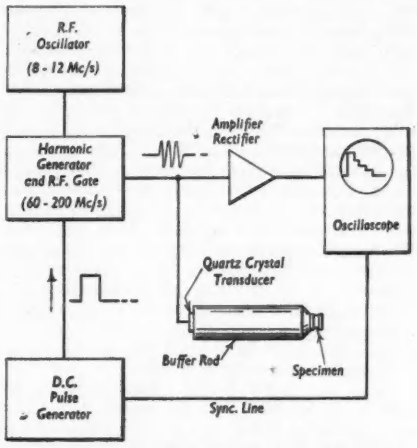
William Kelly had actually worked out his method of converting iron into steel with a stream of air through molten metal some time before 1857, the year in which he received the patent that ushered in the official beginning of American steel-making. Financial difficulties, lack of control and inadequate facilities prevented him from going into large production and getting protection, until Sir Henry Bessemer came over to take out American rights on a similar method. The Patent Office honoured Mr. Kelly's claims and D. J. Morrell promptly bought an interest in them. This partnership eventually resulted in the first commercial quantity of steel made in America by the pneumatic process at Wyandotte, Michigan, in 1864. Even after the Kelly patents were granted and the Bessemer method was known and understood in this country, some time was necessary before large-scale operations got under way. Imported steel used for rails was valued at 150 dollars a ton in 1864, the year when the standard gauge railway was approved by President Lincoln for the whole country, and the year when George Stuntz, hunting gold, found the first specimen of pure hematite iron ore in Minnesota, later to become known as "Minnesota, No. 1 Bessemer" in the trade. Almost at the same time Lewis Howell Merritt found the red dust that led to the discovery and the development of the Mesabi Iron Range. During these same years there was founded in Cleveland and northern Ohio the vast industrial complex that now embraces that region, chiefly an iron and steel centre. Pittsburg had become a natural centre for trade from the east down the Ohio Valley long before steel entered the picture, but the discovery of the uses of coal in Western Pennsylvania and Eastern Ohio, near Youngstown, eventually formed an important industrial axis which has in more recent years come to be an "American Ruhr," and is still growing.

The impetus which came, slowly at first, from the granting of the Kelly patent and the licensing of American firms to use Sir Henry Bessemer's converter, grew and affected the fortunes of the United States before the end of the century. Some of the most spectacular names in American business and finance are important in this story of industrial enterprise and material advancement; Rockefeller, Gary, Morgan, Schwab, and the rest. The achievements of the century that is now being celebrated have eclipsed the fondest expectations of both Kelly and Bessemer, and the end is not yet in sight. As the entire country joins the industry in celebrating this century of steel growth, it is a striking coincidence that at this time a new design of converter has sprung into prominence. Instead of air, the new one uses oxygen, together with some other modifications differing from the designs of Kelly and Bessemer. At the same time, many other new departures are in experiment in the steel industry—all of which suggests that the second century appears to have an auspicious beginning. Such innovations as the direct reduction of iron ores, producing steel without the intermediate pig iron stage, the continuous casting of ingots and billets, and the rolling of sheet from slab in a single-stand planetary mill, are all examples of the progressive spirit to be found in the steel industry to-day. If only a few of these new ideas develop into contributions comparable to the converter process, there will be great advances in the century ahead.

Elastic Moduli of Diamonds

AN ultrasonic technique for accurately measuring the elastic moduli of small specimens of a wide variety of materials has been developed at the Bell Telephone Laboratories, of Murray Hill, New Jersey. With suitable auxiliary equipment, the method can be applied to specimens under widely varying conditions of temperature and pressure. The diamond is of particular interest since there are very few records of its elastic moduli.

The ultrasonic technique now developed is indicated in the accompanying diagram. It consists essentially of transmitting short trains



Block diagram showing ultrasonic technique for determining the elastic moduli of materials

of high-frequency mechanical waves into the specimen and determining their velocity of propagation. From this data and the known density of the specimen, the elastic moduli can be calculated. In the work with diamond, both longitudinal and shear waves were used, providing data for determining its three elastic moduli. Flat and parallel surfaces were ground on opposite sides of the diamond and its thickness was measured very precisely. The specimen was then fastened to one end of a fused silica "buffer" rod by means of a thin film of viscous liquid. A suitable quartz transducer was attached to the opposite end of the buffer. Repeated trains of ultrasonic waves at frequencies up to 200 Mc/s generated by the transducer were transmitted along the buffer rod. These wave trains were principally reflected at the buffer-specimen interface, but were also partially transmitted into the specimen and reflected back and forth between its parallel surfaces, resulting in a series of multiple reflections. At certain critical frequencies, these echoes were precisely in phase and combined to give rise to a characteristic pattern on an oscilloscope responsive to the transducer. The velocity of propagation in the specimen could then be determined from these frequencies and the thickness; and from a knowledge of the density, the adiabatic elastic constants were computed.

Two diamonds were used in these studies. Each stone before cutting was a natural dodecahedron of a pale yellow colour and quite transparent. Both were so-called "Type I" diamonds, as evidenced by a strong optical absorption at 8 microns wavelength, and each was a single crystal as determined by X-ray reflection patterns. Expressed in units of 10^{12} dynes per square centimetre, the elastic moduli were $10{\cdot}76 \pm 0{\cdot}6$ per cent for C_{11}; $1{\cdot}25 \pm 5{\cdot}4$ per cent for C_{12}; and $5{\cdot}76 \pm 0{\cdot}3$ per cent for C_{44}. While the value for C_{11} agrees reasonably well with previous measurements, the value for C_{12} is much smaller and that for C_{44} larger than other workers have reported.

Continuous Processing Line for Non-Ferrous Tubing

The growing American market for non-ferrous tubing in a ¼in to 1in O.D. range, used in such fields as refrigeration, condensers, air-conditioning, heating and plumbing, and automotive tubing, has created a demand for this material to be finish-drawn, straightened, cut to length and recoiled directly from long coils of stock at a high production rate. All of these operations can now be performed continuously on the "Lomatic" tube processing line described here. The equipment has already found widespread acceptance in the American non-ferrous industry and is used in the finishing of copper, brass and aluminium tubing.

IN response to a current demand in the United States for copper, brass and aluminium tubing, in a range from ¼in to 1in O.D., to be processed at a high production rate, an interesting machine has been developed by the Loma Machine Manufacturing Company of New York. Known as a "Lomatic" line, the equipment is capable of finish-drawing, straightening, cutting to length and recoiling tubular stock directly from long coils. Compared to conventional, separate tube drawing and straightening and cutting to length operations, the new single-operation machine offers the following major advantages: —(1) Greater output rate with continuous operation at high speed; (2) reduced labour cost with only one operator being required; (3) improved straightness due to the tube being straightened in two planes; (4) perfect roundness obtained by the straight line drawing action; (5) reduced floor space need with intermediate transport and storage eliminated; and (6) ease of packaging with the recoiled tubing being ready for despatch in cartons or boxes.

As shown in Fig. 3, the complete line comprises an uncoiler, a drawbench, a roller straightener, a flying cut-off, an automatic discharge conveyor and a recoiler. However, it is possible to eliminate one or more of these components if the particular processing applications do not require them. Thus, the drawbench may be eliminated if finish-drawn stock is obtained from the bullblocks, or the recoiler may be eliminated if only straight lengths are to be produced. All components required for a specific sequence of operations are interlocked mechanically and electrically into one integrated and synchronised line which is controlled by only one operator. In a representative tube-finishing operation, coils of tubing weighing several hundred pounds are received from the bullblocks and are loaded on to the uncoiler or pay-off table of the line. One end of each coil is then pointed on a swaging machine, and, if the floating plug method of drawing is used, the plug is swaged into the tube end during the pointing operation. The "Lomatic" machine operator has ample free time during the run of a coil through the line to point the next coil without requiring the assistance of a helper.

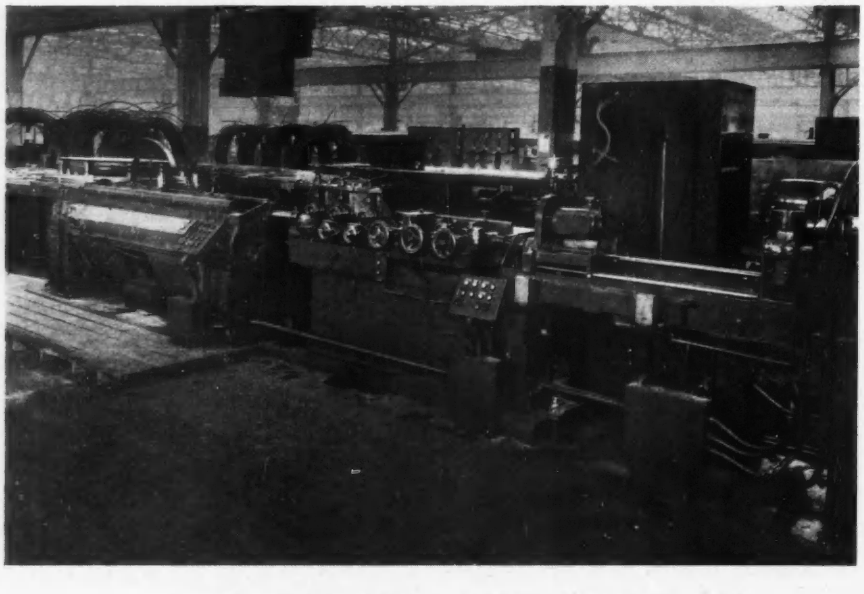


Fig. 1—Roller straightener and flying cut-off saw

Continuous Drawbench

The remarkable productivity of the "Lomatic" line is largely due to its continuously operating high-speed drawbench. This machine allows a final straight line draught of about 25 per cent to be applied to the tubing before straightening, cut-off and recoiling are effected. With the coil of tubing resting on the uncoiler, the pointed end is inserted into the die of the drawbench by the operator. The pointed end normally contains the floating plug, unless the application calls for "sinking" instead of drawing. The stock is pulled continuously through the tungsten carbide die by the back-and-forth movements of two carriages with built-in jaws effecting a reciprocating movement, so that one carriage moving forward pulls the tube through the die while the other carriage moves back.

The gripping jaws close and open automatically when the movement of the carriage is reversed, and the movements of the carriages overlap in such a way that a continuous uniform advance of the stock through the die is obtained. The back-and-forth movement of the two carriages is controlled by cams cut into two rotating drums disposed underneath the frame of the drawbench. These drums are operated from the main motor, which is connected to the drum shaft by a gear drive. Special provision is made for the adjustment of the carriageways, to obtain the closest possible fit, free of play. The gripping jaws built into the carriages are of great length and of a special shape, so that they contact the tube from all sides and operate under a low specific pressure. This design eliminates the risk of surface marks being applied to the tubing by the pulling action. The drawing die, mounted in a rigid cast iron die stand, is lodged in a die holder of spherical shape, so that its correct position can readily be adjusted to ensure the straight line advance of the stock through the drawbench. Space is provided for a guide die ahead of the drawing die to secure the correct position of the plug, when a floating plug is used. Upon the insertion of a new coil, its pointed end is gripped by auxiliary jaws attached to the first carriage. This point may be very short since the carriage moves close to the die.

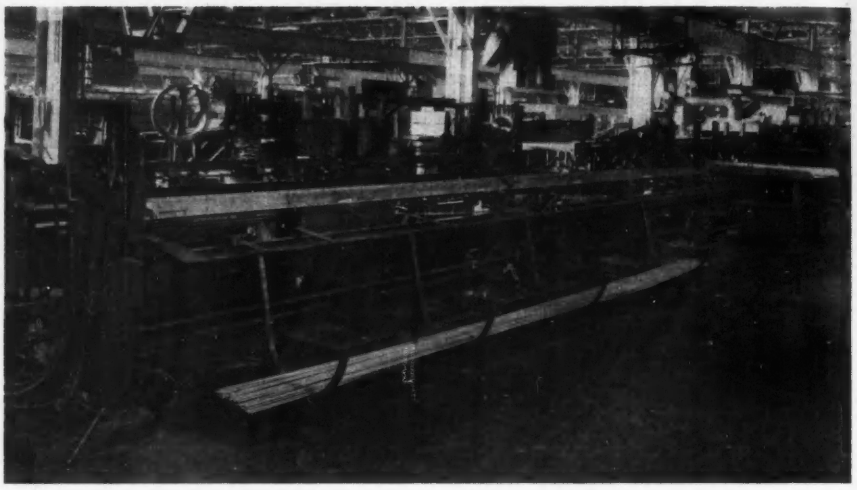


Fig. 2—Discharge conveyor with air-operated pushers and cradles holding straight lengths of copper tubing

Roller Straightener

The tube emerging from the drawbench passes through a vertical and a horizontal set of straightening rollers mounted in tandem, as shown in Fig. 4. Each roller straightener comprises six rollers, three of which are positively driven through gearing by a common motor. To give the straightening effect the rollers are adjustable out of line by handwheels which actuate the adjusting screws of the roller sliding saddles. Accurately calibrated scales are provided to facilitate the exact setting of the saddles. The rollers are mounted on overhung shafts and are thus not obscured in any way, the operator having a clear view of the stock along the entire length of the straightener. The rollers

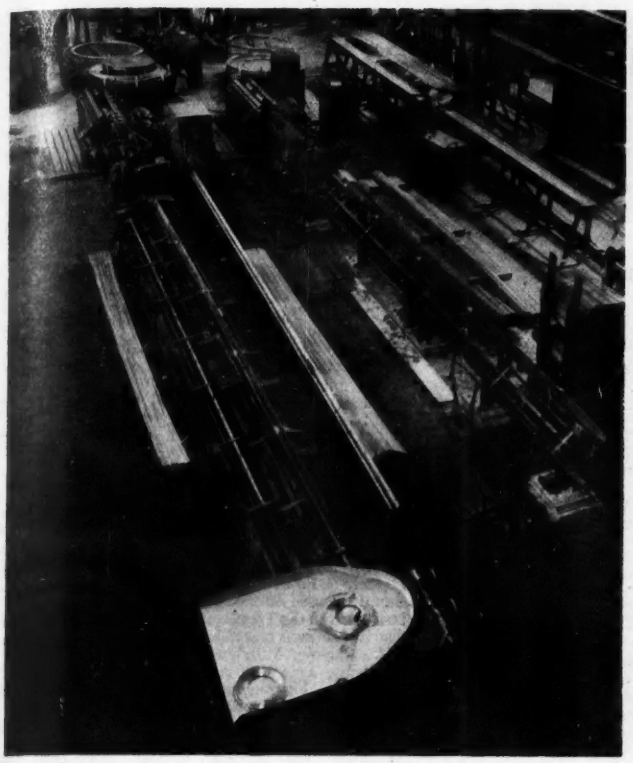


Fig. 3—Overall view of "Lomatic" tube processing lines installed at the Cleveland works of the Chase Brass and Copper Company

are made of tool steel and have ground and polished faces hardened to Rockwell C-56 minimum. Each roller is grooved to suit two sizes of tubing and can quickly and easily be reversed or exchanged by loosening a nut and removing a horseshoe retaining washer. All shafts of the straightener run on anti-friction bearings and its gearing is lubricated by an oil bath. Adjustable felt wipers are provided on the first four rollers to ensure the cleanliness of the stock. A marking roller bracket is mounted facing one roller to facilitate marking the stock with the dimension or trade name as it passes through the machine.

The tubing leaving the roller straightener feeds into the adjacent flying saw, which is illustrated in Fig. 1. The clamping and sawing of the tubing is performed at the full operating speed of the line, so that this operating speed constitutes the actual output capacity of the machine. The blade of the flying saw is mounted on the shaft of a special lightweight, high-speed motor. During the advance of the saw, the motor on which the saw blade is mounted effects also a downward movement, controlled by the slope of a guide bar. During the return movement into the rest position, the saw remains on the highest level, so that the blade is above the advancing stock. The downward movement for the cutting operation can be controlled by adjusting the height of the saw motor relative to the guide bar in accordance with the size of the saw blade and the size of the stock. The advance and return movements of the saw are controlled by a combination air-oil cylinder built into the frame of the machine. The start of the advance movement is actuated by a limit switch adjustably mounted in the delivery table. The position of this switch determines the length of straight tubing being cut. During the cut, the tube is held by collet clamps disposed near the saw blade, which automatically close before the saw cut starts and open automatically at the end of the advance stroke. The cut tube is pulled out of the saw by a pair of motor-driven pinch rollers mounted on the saw frame. The first pointed end of the stock is cut off automatically once it has advanced beyond the saw blade, and it drops out of the machine without requiring any handling or stoppage of the operation.

Upon leaving the flying saw, any one of the following three operations may be performed, depending on the end product requirements and the arrangement of the line :—(*a*) the straight, cut-to-length tubing is piled in cradles mounted adjacent to the discharge conveyor ; (*b*) if a very precise cut-off length with a $^{1}/_{32}$in tolerance is required, the tubes are cut with a slight overlength on the flying saw, and a second cut is effected by a precision cut-to-length saw built into the discharge path of the tubing. After this second cut, the tubes are automatically discharged into the piling cradles ; (*c*) if the tubing is required in the form of pancake, dual-layer or bunch type coils, the stock is guided to a recoiler mounted at the end of the line. This unit forms the desired coil shape by means of two stationary and one adjustable roller and finally discharges the coil.

In arrangement (*a*) the tube travels along the open table section upon leaving the flying saw and is discharged into cradles by air-operated pushers, as illustrated in Fig. 2.

In arrangement (*b*) the tube, while travelling along the discharge conveyor, is transferred to an adjacent and parallel live vee-groove roller conveyor. On this conveyor one end of the tube is pushed against an adjustable stop, while the other end is cut to precision length by a circular saw mounted at the end of the conveyor. The saw is powered by a lightweight, high-speed motor and is traversed by an air cylinder. After the precision cut, the tube is automatically discharged into cradles, as in arrangement (*a*).

In arrangement (*c*) the tube travels along the saw discharge table and enters the bellmouth of the recoiler entry guide, shown in Fig. 5. This tubular guide is aligned with the pair of entry feed rollers, one of which is adjustable by means of the handwheel provided to suit the tube size being processed. The feed rollers are driven from the main gearbox of the recoiler by universal joint spindles. The coil of tubing is formed between two stationary and one adjustable roller, also driven from the gearbox by universal joint spindles. The movement of the adjustable roller, during the formation of the coil, is obtained by the action of a cam, which is linked to the roller by a system of levers. Cam rotation is started when the end of the tube has entered the machine by a switch mounted behind the feed rollers. As a single rotation of the cam has to produce coils of various lengths, change gears are provided to vary its speed of rotation. The recoiler is driven by a two-speed motor, the fast speed of which comes into effect once the flying saw has completed its cut. In this manner, a gap is created between subsequent coils, allowing them to be handled individually, without overlap.

The accompanying illustrations relate particularly to two "Lomatic" lines which are processing copper and brass tubing at the works of the Chase Brass and Copper Company in Cleveland, Ohio. These machines handle $\frac{1}{4}$in to $\frac{3}{4}$in O.D. tubing at an output rate of 200ft per minute. The stock is finished either in straight lengths within an 8ft to 30ft cut-off range, in pancake or dual-layer coils ranging from 25ft to 100ft length, and also in bunch type coils weighing 100 lb or 200 lb. The machines have been in operation since the beginning of the year.

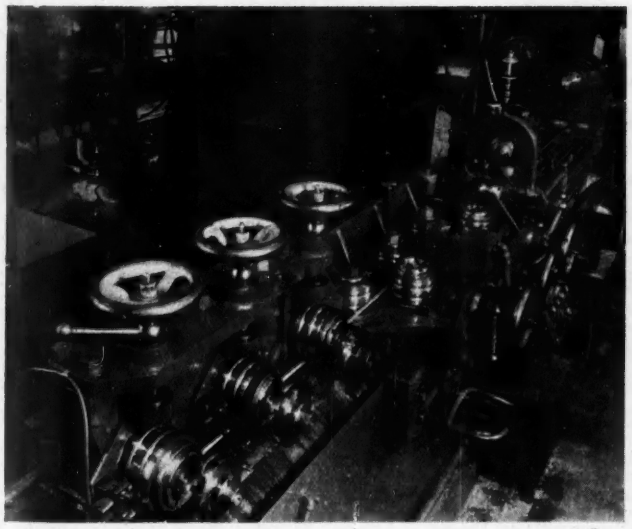


Fig. 4—Vertical and horizontal straightening rollers in tandem, with flying cut-off saw in background

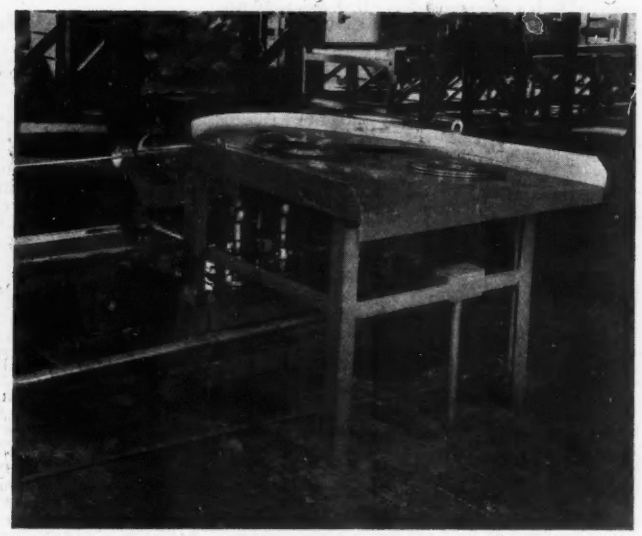


Fig. 5—Exit side of "Lomatic" line with recoiler set up to produce dual-layer coils of copper tubing

Personal and Business

Appointments

MR. DOUGLAS BROWN has been appointed contracts sales manager of Black and Decker, Ltd.

MR. M. RATSCHUNAS has been appointed direct factory representative for Sweden of Simms Motor Units, Ltd.

DESOUTTER BROTHERS, Ltd., has announced that Mr. B. E. Wheadon has been appointed technical sales manager.

MR. F. B. COPE, A.M.I.E.E., has been elected honorary general secretary of the Association of Scientific Workers.

MR. G. S. WEBSTER has been placed in charge of the Stoke upon Trent sub-office of the English Electric Company, Ltd.

MR. W. HAYNES has been appointed Midland area sales manager of Whitehouse Industries, Ltd., Philidas Locknut Division.

ALAN MUNTZ AND CO., Ltd., has announced that Sir Harold Roxbee Cox, M.I.Mech.E., and Mr. K. I. Geddes have been appointed directors.

MR. ARTHUR NORMAN GUYLEE has been appointed managing director of Frank Guylee and Son, Ltd., in succession to his father, Mr. Frank Guylee.

MR. ERIC G. FIELDING, publicity manager of Vickers, Ltd., has been elected president of the Incorporated Advertising Managers' Association.

MR. H. S. WHEELER has been appointed engineering assistant works manager at the Gravesend works of W. T. Henley's Telegraph Works Company, Ltd.

MR. A. J. C. MACLEOD, A.M.I.E.E., has been appointed export manager of the Lancashire Dynamo Group, and Mr. Peter H. Jackson has been appointed an assistant sales manager.

MR. H. A. LUSS has been appointed chairman of the nuclear group of the Scientific Instrument Makers' Association. He has also been appointed deputy chairman of Isotope Developments, Ltd.

THE FAIREY AVIATION COMPANY, Ltd., has announced that Group Captain Gordon Slade has been appointed superintendent of flying and Mr. Peter Twiss has been appointed chief test pilot.

COLONEL D. G. N. LLOYD-LOWLES has been appointed chairman of the Amber Group of companies. Mr. G. C. Baker, group secretary, has been appointed a director of Amber Chemical Industries, Ltd.

ASSOCIATED BRITISH ENGINEERING has announced that Mr. Alexander Belch has been appointed a director of its subsidiary companies, W. Widdop and Co., Ltd., and the Free Piston Engine Company, Ltd.

MR. D. CRAIG has been appointed melting shops superintendent of Steel, Peech and Tozer, a branch of the United Steel Companies, Ltd., in succession to Mr. J. T. Brookes, who has retired after fifty years' service.

THE WALLSEND SLIPWAY AND ENGINEERING COMPANY, Ltd., has announced that Mr. James Gilchrist has been appointed chairman in succession to the late Mr. J. W. Elliott, and Mr. Sheriton C. Swan has been appointed a director.

MR. F. W. SKELCHER, M.I.E.E., M.I.Mech.E., chief generation engineer (operations) of the Midlands division of the Central Electricity Authority, has been appointed deputy chief engineer (generation and system operation) of the Authority.

MR. F. BUCKLAND has been appointed secretary and office manager of the United Coke and Chemicals Company, Ltd., and of the ore mining branch of the United Steel Companies, Ltd., in succession to Mr. S. Bacon, who has retired after forty-nine years' service.

THE ENGLISH ELECTRIC COMPANY, Ltd., has announced that Mr. Victor H. F. Hopkins, M.I. Mech.E., has been appointed manager of engineering, and will be responsible for all technical departments concerned with the design, development, production, and operation of the company's diesel engines.

REEDS PAPER GROUP has announced the following appointments :—Mr. S. W. Barrow has relinquished his post as general manager, Aylesford Paper Mills and has been appointed superintendent of mills ; he has also been appointed a director of the London Paper Mills Company, Ltd., the Sun Paper Mill Company, Ltd., and Colthrop Board and Paper Mills, Ltd. Mr. D. Marsden has been appointed general manager at Tovil and Bridge Mills in succession to Mr. F. W. Amies, who has been appointed general manager, Aylesford Paper Mills. Mr. R. E. R. Green has been appointed a director of Empire Paper Mills, Ltd. Mr. R. Carter has been appointed a director and general manager of E. R. Freeman and Westcott, Ltd., and has relinquished his post as commercial manager, Aylesford Paper Mills. Mr. L. G. Sharp has been appointed to succeed Mr. Carter at Aylesford.

Business Announcements

MR. I. M. O. HUTCHISON, joint managing director of the Balfour group of companies, has left by air for America for a short goodwill tour.

SCIAKY ELECTRIC WELDING MACHINES, Ltd., Slough, states that Mr. E. C. Longmore has been transferred to its northern area sales staff.

WM. BEARDMORE AND CO., Ltd., states that its London office address has been changed to 11, Hamilton Place, Piccadilly, W.1. (telephone, Grosvenor 8786).

SIR WILLIAM HALCROW AND PARTNERS state that they have taken into partnership Mr. C. K. Haswell, M.I.C.E., Mr. R. Carey, M.I.C.E., and Mr. H. Ridehalgh, M.I.C.E.

INTERNATIONAL AERADIA, Ltd., states that it has established a Middle East office at Graham Station, Beirut, Lebanon, under the management of Mr. Sulayman Alamuddin.

THE TRIPLEX GROUP OF COMPANIES states that Charles S. W. Grigg, Ltd., has moved to new premises at 65–67, Hanworth Road, Hounslow, Middlesex (telephone, Hounslow 8385).

IMPERIAL CHEMICAL INDUSTRIES, Ltd., is seeking permission to develop a site of 1000 acres on the Severn, in the Thornbury rural district, for the manufacture of organic and inorganic chemicals.

LAURENCE, SCOTT AND ELECTROMOTORS, Ltd., states that the address of its publicity manager's office has been changed to Manfield House (Fourth Floor), Southampton Street, Strand, London, W.C.2, (telephone, Temple Bar 6777).

THE SOCIETY OF INDUSTRIAL RADIOLOGY AND ALLIED METHODS OF NON DESTRUCTIVE TESTING, 2, Tomswood Terrace, Barkingside, Essex, states that its name has been changed to the Non-Destructive Testing Society of Great Britain.

JOHNSON TRETON, Ltd., Arnold Road, Tooting, London, S.E.17, states that its name has been changed to Johnson Structures, Ltd., and that the name of Johnson Treton Holdings, Ltd., has been changed to Johnson Holdings (Mitcham), Ltd.

VICKERS-ARMSTRONGS, Ltd., states that a licence agreement has been concluded between Vickers-Armstrongs (Engineers), Ltd., and Sulzer Brothers, Ltd., Winterthur, Switzerland, for the manufacture of Sulzer marine diesel engines up to 24,000 b.h.p. The agreement also enables associates of the licensees, Cockatoo Docks and Engineering Company, Pty., Ltd., Sydney, Australia, and Canadian Vickers, Ltd., Montreal, Canada, to build Sulzer engines under licence.

Contracts

SAUNDERS-ROE, Ltd., has received an order from the Federal German Republic for ten Saunders-Roe light helicopters for service with the armed forces.

THE HAWKER SIDDELEY GROUP announces that A. V. Roe Canada is to supply "CF-100" aircraft to the Belgian Air Force under the U.S. Mutual Aid Programme. The contract is valued at 43,000,000 dollars, one-quarter of which is devoted to spares and support. "CF-100" all-weather fighters are at present in service in Europe in R.C.A.F. squadrons.

THE HARLAND ENGINEERING COMPANY, Ltd., Alloa, Scotland, has received a contract from the Jamaica Public Service Company, Ltd., for generating plant to be installed in Maggotty Falls power station. The order includes a "Harland-Morgan Smith" hydraulic turbine rated at 8400 b.h.p. under a net head of 290ft, driving a 7500kVA "Harland" a.c. synchronous generator.

WATES, Ltd., has been awarded a contract valued at £326,620 for building the new American Embassy which is to occupy the whole of the west side of Grosvenor Square, W.1. The new building will be 310ft long and have an original grille-like design for the façade. It is estimated that the structure will be completed in twelve months. Excavation of 30,000 cubic yards for the foundations will be necessary. Concrete cast on the site will total 13,000 cubic yards and an additional 4000 cubic yards of precast and prestressed concrete will also be used. The architects are Messrs. Eero Saarinen and Associates, in association with Messrs. Yorke, Rosenberg and Mardall. The consulting structural engineer is Mr. Felix J. Samuely, M.I.C.E.

THE B.P. TANKER COMPANY, Ltd., has announced a building programme consisting of twenty-six oil tankers. The orders have been placed as follows:—John Brown and Co., Ltd., two of 65,000 tons and one of 50,000 tons ; Cammell Laird and Co., Ltd., two of 65,000 tons ; Fairfield Shipbuilding and Engineering Company, Ltd., one of 65,000 tons and one of 50,000 tons ; William Hamilton and Co., Ltd., one of 15,500 tons ; Harland and Wolff, Ltd., three of 50,000 tons and three of 15,500 tons at Belfast, and one of 15,500 tons at Govan ; Hawthorn Leslie and Co., Ltd., two of 34,500 tons ; Lithgows, Ltd., one of 34,500 tons ; Alexander Stephen and Sons, Ltd., one of 50,000 tons ; Swan, Hunter and Wigham Richardson, Ltd., two of 65,000 tons ; J. L. Thompson and Sons, Ltd., two of 34,500 tons ; Vickers-Armstrongs, Ltd., three of 50,000 tons at Barrow.

BRITISH TRANSPORT WATERWAYS has placed contracts for new equipment as follows :—Richard Dunston, Ltd., Thorne, Nr. Doncaster, two bottom-tipping hopper boats and five dredging hoppers ; J. S. Watson (Gainsborough), Ltd., five dredging hoppers ; E. C. Jones and Son (Brentford), Ltd., Brentford, one 60 h.p. diesel tug (all the vessels will be for use on the Trent Navigation). For the Watford district contracts placed are: Ruddock and Meigham, Ltd., Harrow, Middlesex, foundation and floor of warehouse extension at Brentford ; Ludwell and Co., Ltd., Leamington Spa, construction of the extension ; Thomas Smith and Sons (Rodley), Ltd., Rodley, nr. Leeds, three crawler-mounted grabbing cranes. For trading between the Mersey and the Midlands three powered, all-steel traffic craft and three butty boats have been ordered from I. Pimblott and Sons, Ltd., Northwich. It is also proposed to purchase two 10-ton diesel tractor units, two platform lorries, six semi-trailers for use in the traffic fleet at Leeds, and two 10-ton tractors, four 10-ton trailers and two 6-ton lorries for use at Nottingham. Bank protection work, by concrete piling, is to be carried out by direct labour on the Grand Union Canal, Leeds and Liverpool Canal, at Hartshill on the Coventry Canal, and Hillmorton on the Oxford Canal. A narrow length of channel of the River Calder near Calder Vale Staith is to be widened so as to assist navigation by compartment boats, and a new Rugby district office with workshop facilities to serve Rugby and Warwick districts is to be provided at Hillmorton.

Miscellanea

THE SHIPPING FEDERATION.—On Tuesday last, the new headquarters in the Minories in the City of London of the Shipping Federation, of which Sir Donald Anderson is the chairman, was opened by Sir Thomas Williamson, the chairman of the Trade Union Congress.

UTILITY POWER HOUSE.—We understand that Auto Diesels, Ltd., Uxbridge, is building "unitised" skid-mounted power plants designed for oilfield exploration. Up to 375kVA are said to be obtainable from equipment consisting of three Leyland-Auto diesel generating sets arranged in parallel.

CANADIAN POWER PROJECT.—We are informed that the new hydro-electric power project at Chutes-des-Passes, on the Upper Peribonka River in Quebec, involves blasting a tunnel 35ft in diameter by 6 miles long to connect the reservoir with an underground power-house having five 200,000 h.p. turbo-generators using a gross head of 635ft. A second tunnel, 1¼ miles in length, discharges the waters into the Peribonka River for use again in the Saguenay power stations. When completed in 1960 the project will add 1,000,000 h.p. to the power network of the Aluminum Company of Canada, Ltd., for the smelting of aluminium.

PROTECTIVE HELMETS.—A study has been made by the Road Research Laboratory of records of 7010 accidents in the Metropolitan Police District in 1954–55, in which motor cyclists were injured. In speed restricted areas, for motor cyclists wearing helmets, only 17 had head injuries for every 100 who had injuries to other parts of the body. Of those not wearing helmets, 27 had head injuries for every 100 with other injuries. The corresponding figures for unrestricted areas are 26 and 38. Among the 7010 casualties examined in this investigation the risk of death was reduced by 30 per cent for those wearing helmets in speed restricted areas and by 50 per cent elsewhere ; accidental deaths number about 1000 per annum. If the distribution of crash helmets is assumed to be completely random, this shows that the wearing of a helmet may be advisable.

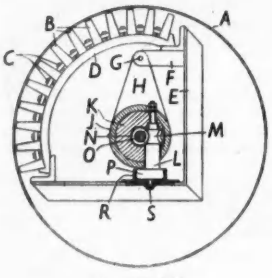
British Patent Specifications

When an invention is communicated from abroad the name and address of the communicator are printed in italics. When an abridgment is not illustrated the specification is without drawings. The date first given is the date of application; the second date, at the end of the abridgment, is the date of publication of the complete specification. Copies of specifications may be obtained at the Patent Office Sales Branch, 15, Southampton Buildings, Chancery Lane, W.C.2, 3s. 6d. each.

METALLURGY

777,548. September 26, 1955. MAGNETIC SEPARATOR, Aktiengesellschaft für Unternehmungen der Eisen- und Stahlindustrie, Altendorferstrasse 103, Essen, Germany.

The invention provides a magnetic separator comprising permanent magnets arranged in series in the direction of the movement of the material to be separated, and mounted on a frame which is adjustable during operation, to alter the distance between the magnets and the surface of the separator which carries the material. As the drawing shows, within a rotating drum *A* the lower portions of magnets *B* are connected by clamping devices *C* to arch-shaped mounting strips *D*, which extend beneath the surface of the drum. The mounting strips are supported by



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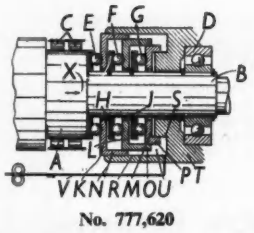
a frame *E*. This frame carries an arm *F* pivoted at a point *G* to an arm *H*, above the axis of the rotation of the drum. The arm *H* is fixed to a sleeve *J*, which is non-rotatably mounted on a hollow shaft *K* which is stationary when the separator drum rotates. The drum is rotatably supported on the shaft *K* at both ends. An adjusting shaft *L* carries a worm wheel *M* which meshes with a worm *N* fixed to a shaft *O* within the hollow shaft *K*. The drive shaft *O* projects from the end of the shaft *K* so that it can be rotated manually. Connected to one end of the adjusting shaft *L* is an eccentric *P*, which co-acts with the guide bars *R* on the frame *E*. When it is desired to vary the distance between the magnets and the inner surface of the drum the drive shaft *O* is rotated. As a result the eccentric *P* is rotated in the guide bars *R*, causing the supporting frame *E* to tilt about the point *G* to increase or decrease gradually the distance between the magnets and the inner surface of the drum.—*June* 26, 1957.

BEARINGS AND SUPPORTS

777,620. March 7, 1955.—AXIAL THRUST BEARINGS, Daimler-Benz Aktiengesellschaft, Stuttgart-Unterturkheim, Germany.

The invention concerns improvements relating to axial thrust bearings for hydrostatic gearing in which power is transmitted by displacement of liquid between a pump and motor unit. In such a plant the hydrostatic pressure gives rise to large axial thrusts, and it is sometimes not possible to fit normal thrust bearings. The object of the invention is to obviate this difficulty. From the drawing it will be seen that one member of a hydrostatic gearing fast on a shaft *B* is supported on ball bearings *C* and *D*. Axial thrust bearings *E*, *F* and *G* arranged one behind the other take up axial thrust acting in the direction of arrow *X*. Whereas the bearing *E* receives axial thrust directly from the member *A*, axial thrust is transmitted to bearings *F* and *G* by sprung-on rings or circlips *J* and



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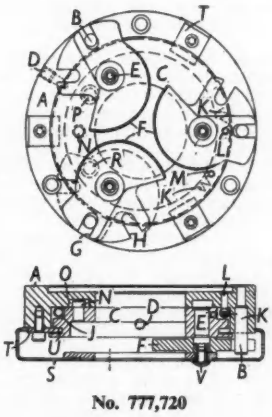
H. The bearing rings *K*, *L* and *M* of the thrust bearings are provided at their circumferences with concentric cylindrical annular parts *N*, *O* and *P*. These parts form pistons sliding one on the other. A housing *T* formed with the cylindrical parts *R* and *S* encloses together with the pistons an annular cylindrical space *U*, to which oil is supplied through a conduit *V*, so that any oil leakage at the sliding surfaces is made up. The thrust acting in the direction of the arrow *X* is distributed between the bearings *E*, *F* and *G* and the pistons *N*, *O* and *P*. If the pistons have the same effective area of cross-section uniform distribution of axial thrust between the bearings is ensured and the thrust is ultimately taken up by the oil in the space *U*. A modified construction is also shown in the specification.—*June* 26, 1957.

TOOLS AND WORKSHOP APPLIANCES

777,720. May 21, 1954.—WORK DRIVERS FOR LATHES AND MACHINE TOOLS, F. Pratt and Co., Ltd., Park Works, Lister Lane, Halifax. (*Inventor: Maurice Akroyd.*)

The invention relates to work drivers for lathes and similar or suitable machine tools of the kind wherein two or more work-engaging cam levers or cam jaws are pivotally supported on a carrier ring floating in an annular housing adapted to act as a driving part of the driver, and has for its object to provide a construction which will accommodate a maximum number of workpiece diameters by utilising a minimum number of interchangeable cam levers or jaws. In the front face of the recessed housing *A* are three equidistantly spaced driving pegs *B* and floating in the recess is a carrier ring *C* which is maintained in position by three spring plungers *D*. Three equidistantly spaced pivot pins *E* are secured to the face of the ring *C* and on each pin is pivotally mounted a detachable cam lever or jaw *F* with a curved inner end. This jaw is serrated for increasing its gripping action on a workpiece. The outer end of each cam *F* has two slots *G* and *H*, radially arranged relative to the pivot points. In the drawings the cams are shown with the slots *G* in engagement with the pegs. Surrounding the carrier ring and entirely housed in an annular recess *J* on the rear face is a helical spring *K* having one of its ends anchored by a peg *L* to the housing *A*, whilst the opposite end is secured by a peg *M* to the ring *C*. A further peg *N* projecting from the rear face of the ring *C* into slot *O* in the body limits movement of the ring relative to the body by abutment with stop pegs *P* and *R* projecting from the body. The ends of the spring-biased plungers *D* co-operate with recesses formed in the periphery of the ring *C*, so that when the dished cover *S* is partially rotated relative to the housing the plungers engage with the dimples and lock the ring and cams *F* in inoperative positions. Movement of the cover *S* in an opposite direction causes the cams to engage and grip a workpiece, and during rotation of the work driver the housing, which is driven by a machine tool, transmits motion to the cams through the driving



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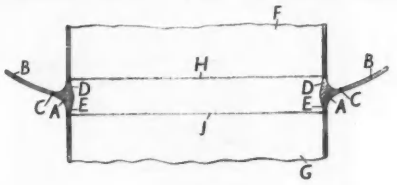
pegs *B*. Guide plates *T* bolted to the housing and projecting into a peripheral recess *U* in the ring retain the latter in the housing. The cover *S* is detachably secured to the front of ring *C* by screws *V* for enclosing a major part of the components; retaining the cam levers on their pivots; for operating the cam levers; and for enhancing the appearance of the appliance. By removing each cam from its pivot and supporting it with the slot *H* in engagement with the pin a workpiece of larger diameter may be accommodated in the work driver. Also, the cam levers may be reversed on their pivots according to the direction of drive.—*June* 26, 1957.

WELDED CONSTRUCTIONS

777,599. October 18, 1954.—PRESSURE VESSELS, Whessoe Ltd., Darlington. (*Inventor: Arthur Francis Gardiner Austin.*)

The connection of branch pipes to pressure vessels gives rise to special stress problems in view of the fact that the stress round the edge of a hole or opening in the vessel at which the branch is to be connected is considerably greater than the stress in the remaining unpierced portion of the vessel. These disadvantages are avoided by the present invention, according to which a ring is located in an aperture in the wall of the vessel and is so shaped that its outer edge conforms to the periphery of the aperture, this outer edge of the ring member being substantially equal in thickness to the wall and being butt welded to the surrounding edge of the wall. A particular form of the invention is illustrated by the drawing, which is a horizontal section through the junction between the vertical wall of a pressure vessel and a horizontal branch pipe. It shows a construction employed in connecting a 12ft diameter branch pipe to a vertical cylindrical pressure vessel, whose diameter is of the order of 37ft, in such a way that the branch extends radially both inside and outside the vessel. In this construction there is employed a forged circular ring member *A*, whose principal plane is curved to correspond to the curvature of the vessel wall *B*. At its outer periphery the ring is of approximately the same thickness as the vessel wall, say 2in, and this outer edge, having been suitably prepared, is butt welded at *C* to the edge of an opening formed in the vessel wall. In section, the ring *A* is very roughly triangular in shape, its thickness increasing from its outer periphery, both on the inside and the outside of the line of the vessel wall,



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so that it provides an annular flange *D* measuring 12ft in diameter, which projects into the interior of the vessel, and a similar flange *E* projecting outwards from the vessel. The interior and the exterior branch pipes *F* and *G* are respectively butt welded at *H* and *J* to the extremities of the flanges *D* and *E*, which are tapered in section so that in the region of the weld they have the same thickness as the walls of the branch pipes. It is to be noted that the contours of the ring *A* are essentially smooth, thereby avoiding any abrupt changes in stress, and that its shape allows radiographical examination not only of the weld *C* joining it to the vessel, but also of the two branch pipe welds *H* and *J*. In constructions where only one branch pipe is required, say an external branch, the sectional shape of the ring member can be modified accordingly to provide only one tapered flange, such as *E*, extending outwards from the line of the vessel wall. The shape of the ring can also be modified in other ways without exceeding the scope of the invention. While a ring member suitable for connecting branch pipes to cylindrical vessels has been described and illustrated, it is understood that the invention is also applicable to vessels of other shapes, including spherical and ellipsoidal vessels.—*June* 26, 1957.

ELECTRICAL ENGINEERING

777,511. March 22, 1955.—ELECTRICAL CONTACT ELEMENTS, Bernard Roy Atkins and David Peter Griffiths, Vale Works, Vale Road, Portslade, Sussex.

The invention relates to electrical contact elements and, more particularly, but not exclusively, to the contact brushes used in dynamo electrical machines. Its object is to provide brushes or other contacts of carbon, graphite or electrographite having a modified contact resistance as compared with the conventional brush. According to the invention, there is provided a method for the deposition of metallic silver within the structure of a porous carbon matrix by impregnating the matrix with an aqueous solution of silver nitrate and removing the solvent by heating to a temperature not exceeding 100 deg. Cent., and subsequently decomposing the silver nitrate by heating it at a temperature below the melting point of silver nitrate in the presence of a gaseous reducing agent. The reducing agent may be gaseous hydrogen or formaldehyde. By this method it is possible to reduce the silver nitrate at a temperature just below its melting point (i.e. 212 deg. Cent.), thereby causing the inner surface of the body to be coated uniformly with silver. By varying the concentration of the silver nitrate solution used for impregnating the porous matrix and, if necesssary, by repeating the process, one or more times, it is possible to obtain products containing between 1 and 60 per cent by weight of metallic silver. In an example a block of porous electrographite previously impregnated with polytetrafluorethylene was found to contain approximately 40 per cent of residual available pore space. The block was boiled for one hour in an aqueous solution of silver nitrate containing 29 grammes of silver nitrate per 100 grammes of water. After cooling the solution to room temperature the block was removed and dried by heating in a current of air at 40 deg. Cent. It was then transferred to a sealed

container, wherein it was heated at a temperature of between 190 deg. and 210 deg. Cent. for one hour in an atmosphere of hydrogen. Subsequently, to ensure complete reduction, the temperature was raised slowly to 300 deg. Cent. After cooling, the block was removed and found to contain 5 per cent by weight of silver. The block was used for the making of brushes for dynamo brushes.—*June* 26, 1957.

TUBE AND PIPE CONNECTIONS

777,697. November 19, 1952.—MEANS FOR CONNECTING OR COUPLING PIPES AND TUBES, Raymond James Mitchell, "Homestead," Garth Hill, Collingham, Near Leeds.

Referring to the drawing, the connecting or coupling means comprises an annular C-shaped sealing member *A* of elastic material such as rubber, preferably which will not be affected by oil or grease. The portions *B* of the sealing member adjacent to the free edges are preformed of opposed hollow frusto-conical shape with the minimum diameter being at the edges *C* which are adjacent but not touching. The sealing member is surrounded by and bonded to a ring *D* in the form of a sleeve having a central annular

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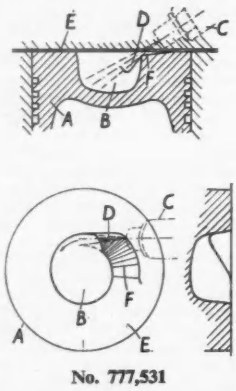
recess *E* which is threaded on each side to receive the screwed ends of pipes. In coupling, the ends of the pipes or tubes are passed into the conical portions *B* of the sealing members by screwing them into the ring *D* so that the portions *B* of the sealing member are stretched around the pipe ends, thus providing an initial seal. Pressure in the pipeline augments the tightness of the seals around the pipe ends.—*June* 26, 1957.

INTERNAL COMBUSTION ENGINES

777,531. July 7, 1955.—ENGINES WITH FUEL INJECTION, AIR COMPRESSION AND SELF-IGNITION, Steyr-Daimler-Puch Aktiengesellschaft, Schonauerstrasse 5, Steyr, Upper Austria.

The object of the invention is to provide an engine in which the intensive turbulent flow about the piston axis is imparted to the combustion air with the minimum possible loss of energy. As shown in the drawing, the piston head *A* comprises a central combustion chamber *B*, into which the fuel is injected from the nozzle *C* through a tangential, trough-shaped recess *D* in the side of the combustion chamber. The portion *F* of the face *E* of the piston is in the form of a helical surface and falls away from the flat end face *E* of the piston round the piston axis to



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the recess *D*. This helically surfaced portion, which has a width corresponding to the length of the recess, is gradually and increasingly inclined relative to the end face of the piston. As can be seen in the lower views, the wall of the combustion chamber *B* constitutes a single complete turn of a spiral, and the helical portion *F* of the end face *E* of the piston runs along the part of the wall of the combustion chamber having the smaller radius while the adjacent recess *D* merges into the part of the wall of the combustion chamber having the largest radial distance. The combustion chamber widens out towards the top and has a flat or slightly curved bottom. A modified construction is also shown in the specification.—*June* 26, 1957.

Launches and Trial Trips

AYRSHIRE, cargo liner; built by the Greenock Dockyard Company, Ltd., for the Clan Line Steamers, Ltd.; length overall 535ft, length between perpendiculars 497ft, breadth moulded 69ft, depth moulded 41ft 7in, deadweight 11,230 tons on 28ft 3in draught, service speed 17 knots; twelve passengers; six holds, cargo capacity 600,000 cubic feet, one 105-ton, two 40-ton, four 15-ton, four 7-ton and twelve 5-ton derricks, electric winches, four 300kW diesel-driven generators; one set of Parsons reaction, triple-expansion, double-reduction, geared turbines, 10,500 service s.h.p. at 112 propeller r.p.m., and 11,550 maximum s.h.p. at 115·5 propeller r.p.m., two Babcock and Wilcox single-pass water-tube boilers supply steam at 415 lb per square inch and 750 deg. Fah. Trial, May 1 and 2.

SUGAR PRODUCER, bulk sugar carrier; built by Hall Russell and Co., Ltd., for Silvertown Services Shipping, Ltd.; length between perpendiculars 370ft, breadth moulded 53ft, depth moulded 28ft, deadweight 6600 tons, four holds, electric winches; Clark-Sulzer six-cylinder, single-acting engine, 3000 b.h.p. at 150 r.p.m. Launch, May 14.

SUNVICTOR, cargo ship; built by the Burntisland Shipbuilding Company, Ltd., for Skibs A/S "Geiruly" Norway; length overall 472ft 6in, length between perpendiculars 450ft, breadth 62ft 11in, depth moulded to upper deck 38ft 6in, draught 29ft 1½in, deadweight 12,950 tons; ten passengers; five cargo holds, complement of 5-ton derricks, three bipod masts, electric winches; three 220kW diesel-driven generators; one set of two-cylinder, impulse-reaction, double-reduction, geared turbines, 5000 s.h.p. at 115 propeller r.p.m.; two water-tube boilers provide steam at 475 lb per square inch and 760 deg. Fah. Trial, May.

British Standards Institution

All British Standard Specifications can be obtained from the Sales Department of the Institution at 2, Park Street, London, W.1.

THE DESIGN AND TESTING OF STEEL OVERHEAD RUNWAY BEAMS

No. 2853 : 1957. Price 5s.—Forty-five organisations, including the important trade and professional associations and government departments, were represented on the committee set up by B.S.I. to meet the request of the Chain Testers' Association of Great Britain for a standard for the design and testing of steel overhead runway beams. Their work has resulted in this illustrated publication, which will serve as an authoritative reference for designers and testers.

The standard is applicable to runway beams made from rolled steel sections, and it lays down those fundamental principles on which the reliability and safety of overhead runways depend. Its application will in no way limit the runway maker's choice of designs.

Among the more important clauses in the publication are those relating to design, materials, fabrication and erection, end stops, testing and inspection, marking and certification. One of the six appendices lists the British Standards applicable to the various materials, &c., used in the construction of the runway beams. Also included in the appendices are a standard form of "Certificate of Test and Thorough Examination of Runway Beams" and of "Certificate of Thorough Examination of Runway Beams."

TESTS FOR INDUSTRIAL CRAWLER AND WHEELED TRACTORS (EXCLUDING UNITS DESIGNED FOR MATERIALS-HANDLING IN FACTORIES

No. 2800 : 1957. Price 5s. Publication in 1951 of B.S. 1744, "Tests for Agricultural Tractors," gave rise to the need for a similar standard by means of which the performance and characteristics of industrial tractors could be determined and expressed.

The new standard has been prepared under the supervision of the Road Engineering Industry Standards Committee, and will, it is expected, be adopted as basic test procedure by the "heavy" tractor industry, as is the case with its counterpart, B.S. 1744 for agricultural tractors. Its first section deals with tests for engine performance, during which horsepower and specific fuel consumption are measured over the full range of engine speeds.

Section 2 deals with drawbar performance tests, carried out with the aid of a drawbar dynamometer, during which measurements of drawbar horsepower, pull and specific fuel consumption are made over the whole range of drawbar pulls. The third section describes a static tilting test, by which it is possible to verify the claims of a manufacturer as to the suitability of his machine for operation on severe gradients. The final section specifies the procedure for final examination and the form in which the test report shall be drawn up.

Technical Reports

The Effect of Series Resistance on the Ignition of Methane-Air Gas Mixtures by Capacitive Discharges (Ref. G/T304). By H. G. Riddlestone, B.Sc. (Eng.), A.M.I.E.E. The British Electrical and Allied Industries Research Association, Thorncroft Manor, Dorking Road, Leatherhead, Surrey. Price 7s. 6d., postage 4d.—The effect of series resistance on the stored energy required to ignite 8·35 per cent methane-air mixtures by capacitive spark discharges has been described in Report Ref. G/T278, for circuits in which the values of capacitance and resistance were less than 850 $\mu\mu$F and 60 ohms respectively. The range of the measurements has now been extended to include capacitances up to 1μF and resistances up to 225,000 ohms, with both tungsten and steel electrodes. Measurements of the actual discharge energies required for ignition with this increased range of circuit conditions has not yet been carried out, but the scope of the present techniques of oscillographic recording of the discharge currents and voltages is being widened to make this possible.

Flame Protection Practice (1956): *Industrial Gas Development Committee Report* 611/56. The Gas Council, 1, Grosvenor Place, London, S.W.1. Since this review was first published in 1950 under the title "Flame Failure Devices—a Review of the Present Position," the technique of flame failure protection has developed sufficiently to warrant this revision, which supersedes the previous publication. The report reviews the various kinds of device which are at present available, setting out their virtues and inherent weaknesses, and showing where each kind is most suitably employed. It also contains a list of the facts which, it is felt, manufacturers of flame failure devices should provide for the benefit of their customers. The report contains recommendations for the correct installation of the various devices, and these recommendations represent the minimum standard which should be attained by all installations with the equipment at present available. With advances in reliability and speed of response, together with a reduction in cost of the fundamentally more satisfactory devices, it is considered that a progressive improvement in this standard may be looked for. The report says that there has been considerable development in the field of multi-burner protection, and this subject is fully considered.

Forthcoming Engagements

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of their insertion, the necessary information should reach this office not later than a fortnight before the meeting. In all cases the TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

BRITISH INTERPLANETARY SOCIETY

Thurs. to Sat., July 18 *to* 20.—JOINT MEETING WITH THE COLLEGE OF AERONAUTICS: College of Aeronautics, Cranfield, Symposium on "High Altitude and Satellite Rockets."

CHEMICAL SOCIETY

To-day, July 12.—Chemistry Department, University of Glasgow. Symposium on "Recent Advances in the Chemistry of Terpenoid Compounds."

INSTITUTE OF THE MOTOR INDUSTRY

Sat. to Sat., Aug. 24 *to* 31.—St. Catharine's College, Cambridge. Eleventh Annual Summer School.

INSTITUTE OF ROAD TRANSPORT ENGINEERS

Thurs., July 18.—LONDON BRANCH: Day visit to the factory of de Havilland Aircraft Company, Ltd., Hatfield, Herts.

INSTITUTION OF MECHANICAL ENGINEERS

Wed., July 17.—S. WALES BRANCH: Visit to Rank Precision Industries (B.A.F.), Ltd., Mitcheldean, Gloucester.

Wed., July 24.—N.W. BRANCH: Visit to Calder Hall Nuclear Power Station.

Sat., Aug. 31.—S. BRANCH: Whole-day visit to the pumping stations of the Mid-Wessex Water Company, Frimley, Surrey.

PLASTICS INSTITUTE

Fri., July 19.—Conference Room, Gallery, National Hall, Olympia, London, W.14, Annual General Meeting, 12 noon.

WOOLWICH POLYTECHNIC

Mon., July 15.—Woolwich Polytechnic Hall, Calderwood Street, Woolwich, London, S.E.18, "Predetermined Motion Times and Their Applications, as Exemplified by the Work Factor System," J. Taggart, 7 p.m.

Advanced Engineering Courses

Annual Summer School of the Institute of the Motor Industry. ST. CATHARINE'S COLLEGE, Cambridge. For one week commencing Saturday, August 24.

Nuclear Power Engineering. SOUTH EAST LONDON TECHNICAL COLLEGE, DEPARTMENT OF ELECTRICAL ENGINEERING AND APPLIED PHYSICS, Lewisham Way, London, S.E.4. Course of eighteen lectures, Tuesdays, 7 p.m. to 9 p.m., commencing November 12. Fee £1 10s.